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ABSTRACT

Addressed to the parents of children taking computer courses in school, this booklet outlines the rationales for computer use in schools and explains for a lay audience the features and functions of computers. A look at the school of the future shows computers aiding the study of reading, writing, arithmetic, geography, and history. The features of computers are then covered in two chapters: the first on the history and distinctive functions of computer systems, and the second on the properties of computer hardware and software, including the general problem solving strategies used by programmers. The three main instructional uses of computers--in computer-assisted learning, problem solving, and literacy--are then explained, with discussions of the realistic goals for computers in education and the esential elements of a successful programming curriculum. The author also points out what parents can do to help their children learn about computers, including using computers in the public library or science museum, or placing computers in scout troops and summer camps. To facilitate computer education at home, the final section discusses the major considerations in buying and using a home computer. An article by Merle Marsh, entitled "Comes the Dawn (If Only I Can Find the Switch)," about a mother's experiences in becoming computer literate is also included. (JW)

PARENT'S GUIDE TO COMPUTERS IN EDUCATION

David Moursund

Price: $3.50 U.S.

David Moursund, the author of this book, has been teaching and writing in the field of computers in education for the past sixteen years. He is a professor at the University of Oregon, holding appointments in the Department of Computer and Information Science and in the Department of Curriculum and Instruction.

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- Author or co-author of ten books and numerous articles.
- Chairman of the University of Oregon's Computer Science Department, 1969-1975.
- Chairman of the Associa.'on for Computing Machinery's Elementary and Secondary Schools Subcommittee, 1978-1982.
- President of the International Council for Computers in Education and Editor-in-Chief of *The Computing Teacher.*

This book is published by the International Council for Computers in Education, a non-profit, tax-exempt professional organization. ICCE is dedicated to improving educational uses of computers and to helping both students and teachers become more computer literate. ICCE publishes *The Computing Teacher,* a journal for teachers and for teachers of teachers. It also publishes over ten booklets of interest to educators.

The booklet prices given below are for **prepaid** orders. On other orders a $2.50 handling and shipping charge will be added.

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PARENT'S GUIDE TO COMPUTERS IN EDUCATION

David Moursund

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Comes the Dawn

(If Only I Can Find the Switch)

by Merle Marsh

NOTE TO READER

This booklet will be most useful to you if used in conjunction with a little hands-on computer experience. You can likely get this experience at a computer store, a local school, or a neighbor's house. Run a few different programs, perhaps including one program that is educational in nature and one designed strictly for entertainment. As you use the computer, keep in mind that many of today's elementary school students have already had similar computer experiences.

PART I — OVERVIEW

The history of the human race can be charted by progress in developing tools. The club, knife and spear helped humans to feed themselves and to protect themselves against attacking animals. Spoken language allowed for improved communication. Picture drawings aided both memory and communication. Much later on this historical scale came the idea of farming, with special tools for planting and harvesting.

Farming contributed to an increased population and to increasing concentrations of people in villages. Farming also contributed to the development of reading, writing and arithmetic. These "mind tools" were needed to help determine when to plant and when to harvest. They were needed to help keep track of the size of one's flock and quantities of food in storage. Surveying was important where annual floods covered the fields.

I tried to enter the Computer Age by quietly sneaking up on the new technology, taking my time to master it before anyone discovered how inept I was at mathematics and anything mechanical. In college I became liberally educated by opting for botany instead of physics, taking two foreign languages to avoid

Reading, writing and arithmetic proved to be such useful tools that they have become the "basics" of a modern education. Our educational system is designed to help all students acquire a functional level of knowledge in them.

Now we have another mind tool, a new aid to human intellectual activity. It is the electronic digital computer. A computer is merely a machine, and we routinely use many other machines. But a computer is a general-purpose aid to problem solving, much as reading, writing and arithmetic are general-purpose aids.

It is probable that elementary and secondary schools that you attended did not have computers for use by students. Until recently computers were large, expensive machines used mainly in business, government and research. While many colleges offered computer courses, these courses were mainly designed for technically-oriented students and/or those seeking a career in the computer field.

The microcomputer, first produced in 1975, has changed this situation. General-purpose microcomputers are now inexpensive enough so that almost every school can afford to own at least one. Likewise, it is no longer unusual for a person to own a computer for use at home for business, educational or entertainment purposes. And there is nothing particularly "micro" about the capabilities of a microcomputer. Some rival the capabilities of the million-dollar computer of twenty years ago.

Eventually, a good working level of knowledge about computers will be considered one of the basics of education, much as reading, writing and arithmetic are today. For more than ten years now, leaders in the field of computer education have advocated that all students should become computer literate—that is, they strongly support the idea that all students should develop a functional level of knowledge and skill in their use.

Support for universal computer literacy is growing quite rapidly. Many school districts have developed plans for integrating computer instruction into their schools and have begun to implement these plans. Still, the majority of today's students have had little or no formal exposure to computers.

The goal of this booklet is to help change that situation. You, a concerned adult, can make a significant contribution to the field of computers in education. If you are a parent with a child in school, you can help your child. This booklet will help you to get started. It provides some ways that you can help improve the computer-related education of your children and other children.

Following this overview, the booklet is divided into seven major sections. A brief summary of each is given below:

School of the Future

Spend a few minutes in a highly computerized "School of the Future." Observe and listen in as Terry, an upper elementary school student, uses a computer to study reading, writing, arithmetic, geography and history.

Introduction to Computers

A computer is a machine, designed as an aid to human intelligence. It is a general-purpose aid to problem solving, useful in every academic area. One way to understand a computer is to see how it is the same as and/or different from a calculator. Another way is to compare it with an electric typewriter, seeing how adding computer features to a typewriter results in a modern word processing system.

Hardware and Software

Some computer systems cost only a few hundred dollars, while others cost many millions of dollars. Computer systems differ markedly in the nature and capability of their hardware (physical machinery) and software (detailed step-by-step sets of directions).

Computers in Education

The field of computers in education can be divided into three major parts. First, computers are a new aid to learn-

mathematics, and studying American history until I considered myself an authority on the Battle of Baltimore in the War of 1812.

The War of 1812 isn't exactly everyone's favorite war, and although it shall always be dear to my heart, it is a topic that I can seldom insert into conversations except when talking to nine-

ing. Computer assisted learning will eventually be a dominant aid to learning. Second, computers affect the content of every academic field. Computers are both an aid to problem solving and a new source of problems. Third, computer and information science is an important discipline in its own right.

What You Can Do

Computer literacy for children can be developed in local libraries, in schools, at your home, at neighbors' homes or in science museums. By following ideas discussed in this section, you can help make more computer-oriented learning opportunities available both to children and to yourself.

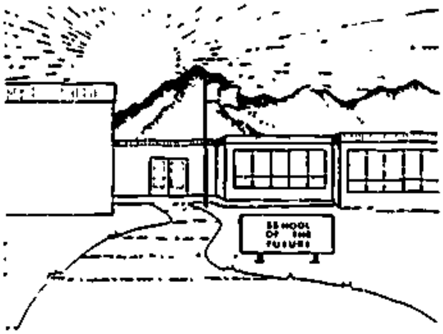
Buyer's Plan

This section is a 4-step process to be used when selecting a computer. Included is a sample *Needs Assessment* and *Implementation Assessment* checklist.

Appendices

As you read this booklet, you are likely to encounter computer-related words that are new to you. The Glossary lists some of the most important ones. After reading this booklet you may want to do some additional reading. The Resources section recommends several books and periodicals.

PART II — SCHOOL OF THE FUTURE



Come with me into the school of the future. As you enter the building, things seem "normal"—that is, much like when you were in school. Students crowd the hallways, talking, laughing, hurrying to class.

Classes have begun, and you enter a classroom. You see the students and teacher, chairs and desks, wall decorations and blackboards, an overhead projector. Along one entire wall are open booths containing television-like display screens and typewriter-like keyboards. These are the computer-assisted learning stations you have come to see.

There is a lot of activity in the room: some students are at their desks, some are in a discussion group with the teacher, while others are busy at the computer-assisted learning stations. You talk with the teacher for a minute. The teacher indicates that small group discussions and working one-on-one with students are more common since computers have come into the classroom. The teacher invites you to look at these learning stations to see why they are a significant aid to students.

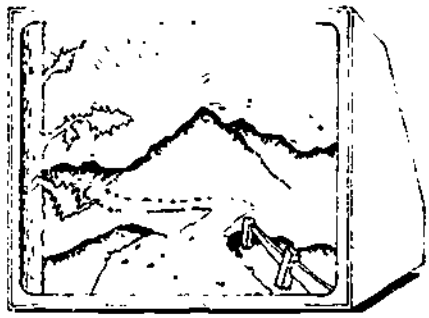
Some of the learning stations are being used by a single student, while others are used by groups of two or three.

year-olds engaging in the study of our national anthem. Realizing that the Age of the Computer was dawning while I was setting in the Age of the Cannon, I decided to tiptoe into the twenty-first century, disguised as a supportive mother helping her ten-year-old son.

The overall atmosphere in the room seems relaxed but busy, with a moderate noise level and quite a bit of student movement about the room.

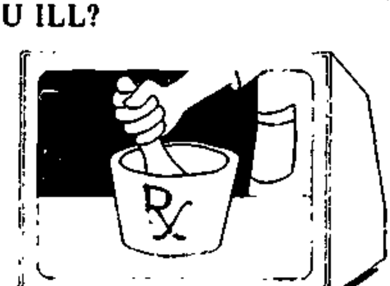
You watch as a student walks up to a computer terminal, turns it on, types in the name TERRY JOHNSON, presses the ENTER key, and puts on a pair of earphones. Terry sees you watching and hands you a pair of earphones so you can listen in. You pull up a chair so that you can see what Terry is doing.

The computer system's display screen lights up with a colorful picture, while a somewhat monotone voice says through the earphones:



GOOD MORNING TERRY. I AM PLEASED THAT YOU ARE AT SCHOOL TODAY. MY DATA BANKS INDICATE THAT YOU HAVE BEEN ABSENT FOR THE PAST WEEK. WERE YOU ILL?

Terry types YES and presses the ENTER key. The computer display changes to an appropriate graphic, and the computer voice continues.



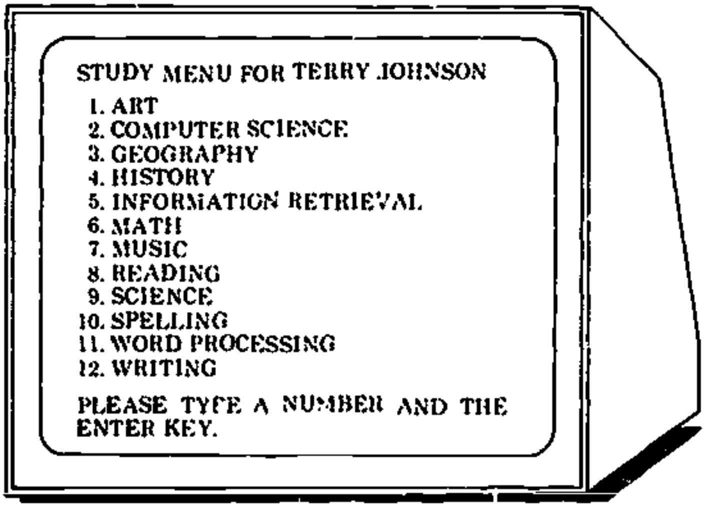
I HOPE IT WASN'T ANYTHING SERIOUS. IT IS GOOD TO HAVE YOU BACK IN SCHOOL. HERE ARE SOME ANNOUNCEMENTS YOU MISSED:

1. YOUR CLASS TRIP TO THE SCIENCE MUSEUM HAS BEEN POSTPONED FOR ONE WEEK.

2. THE SCHOOL NURSE GAVE A TALK ON GOOD EATING HABITS. YOU CAN GET A FREE BOOKLET ON THIS BY ASKING THE NURSE.

3. REMEMBER, NEXT FRIDAY IS A TEACHER WORKDAY. SCHOOL WILL BE CLOSED ON THAT DAY.

WELL, ENOUGH OF THIS CHATTING—IT'S TIME FOR US TO GET TO WORK. MY DATA BANKS INDICATE THAT YOU COULD USE SOME WORK IN READING, GEOGRAPHY AND MATH. BUT SINCE YOU HAVE BEEN ILL, I WILL LET YOU DECIDE WHAT YOU WOULD LIKE TO WORK ON. PLEASE USE THE KEYBOARD TO SELECT A SUBJECT.



Terry selects READING by typing an 8 and the ENTER key. The computer voice thanks Terry for making this choice and displays the first part of a story on the screen. The story is about Marco Polo's travels in the Orient. It is accompanied by detailed maps, a discussion of the terrain and climate, and other information about life in the thirteenth century. The vocabulary used in the story seems quite challenging for a student of Terry's age.

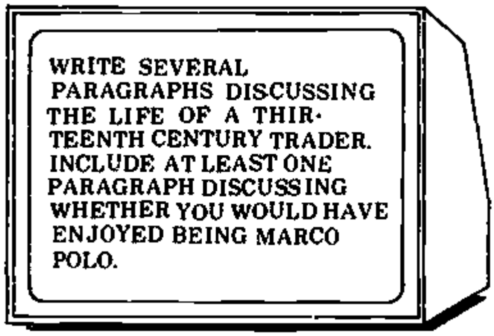
First, I invited one of the local school's computers home for a weekend, and after having signed a statement that I would be responsible for its welfare, discovered that bringing it home was rather like transporting an unassembled bicycle part by part without a box. Over the February ice of the school parking lot, my

At first Terry progresses rapidly, using a control device on the computer keyboard to scroll more text onto the screen. But then Terry pauses, seemingly stuck on a particularly difficult sentence. You notice Terry touch the display screen, rubbing a finger over the first part of the difficult sentence. The computer responds by speaking the sentence over the earphones. One word in the sentence gives Terry particular trouble. Terry types the word on the computer keyboard, and a dictionary definition of it appears on the lower part of the screen.

As Marco Polo is about to set out on another journey, the computer asks Terry to play the role of Marco Polo. Terry is asked to examine the maps, select the route and make decisions about what equipment and trade goods to take along. During this trip Terry is continually asked to make decisions that affect the outcome of the journey. Along the way Terry does the bartering, trying to maximize profits. From time to time the computer screen displays a comment such as, "Bargain harder next time. You lost money on that deal." or, "That mountain pass is blocked by snow at this time of year. Select a different route."

You continue to observe as Terry completes the journey and begins to answer a sequence of questions. The questions test for comprehension as well as understanding of the geography and history of Marco Polo's trips. They also cover some of the mathematics involved in the trip such as kilometers traveled per day, profit on goods bought and sold, and time to complete various trips. Somehow the computer has managed to combine reading with geography and mathematics, the three areas in which the computer suggested that Terry most needed work!

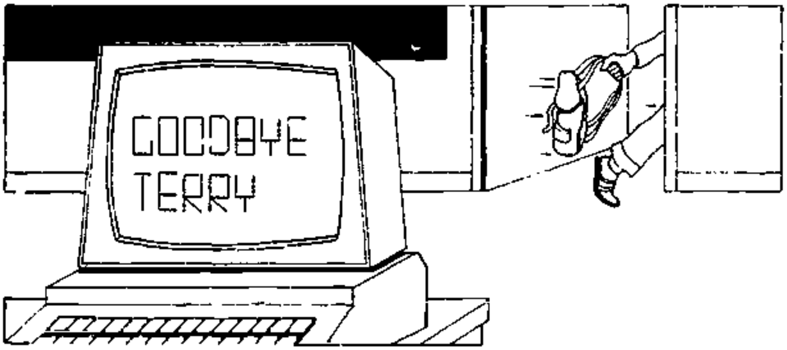
Most of the questions are multiple choice or short answer, although some call for typing in a complete sentence or two. As the lesson seems to be drawing to an end, the computer gives Terry the following assignment.



You notice that Terry is an accomplished touch typist and is quite familiar with the computerized word processing system. After a couple of paragraphs have been written, you observe Terry interrupting the writing to use the computer to look up some information in an encyclopedia. Terry tells you that there is a complete encyclopedia as well as many other reference books on-line to the computer system.

Soon Terry indicates to the computer that the essay is complete. The computer checks Terry's spelling, suggesting that two words seem to be misspelled. It also suggests that one sentence is unusually long and perhaps should be rewritten, and compliments Terry on the word processing skills displayed in doing this exercise. After Terry makes a couple of corrections, the computer places a copy of Terry's writing into the teacher's READING file and indicates that Terry's conference time with the teacher is scheduled for 10:00 the next day. The computer then reminds Terry that tryouts for the class play will begin in a few minutes, and that band practice will be held right after school. Terry hastily types GOODBYE to the computer and rushes off to try out for the play.

son, otherwise known as Computer Kid, and I transported the monitor (which looks like a television set), the tape recorder (which looks like a regular tape recorder), the computer (which looks like a rollerless typewriter), two instruction manuals, the power supply box, and all those cords necessary for hooking up



Does this SCHOOL OF THE FUTURE seem like science fiction to you? It isn't! Everything in the scenario is possible now, using today's computers and today's computer-education technology. Moreover, we now have substantial evidence that students learn more, better and faster in such a computer-assisted learning environment. In addition, this education is increasingly relevant to what these children will encounter in their adult life, at home, at work and at play.

Some children already have access to quite a bit of the computer-assisted learning technology described in the scenario. Perhaps their parents are computer scientists or have purchased a computer for home use. Perhaps they live in an exceptionally wealthy school district or attend an expensive private school. Perhaps the school they attend is an experimental school, designed to test out some ideas for other schools of the future. For such students, the future is now.

It is now clear that computers will continue to increase in availability and usefulness. Today's children will spend their entire adult lives in a world where computers are everyday tools. Computers will be commonplace in most homes as well as in business, government and education.

The critical issue is what happens to today's children—especially, your children. Will they learn about computers and make an easy transition into tomorrow's computerized society, or will they find themselves out of phase with this rapidly changing technology? You can play a significant part in the answering of this question. To do so, you need to increase your knowledge of computers.

PART III — INTRODUCTION TO COMPUTERS

A computer is a machine designed as a general-purpose aid to problem solving. A computer consists of physical machinery (called *hardware*) and detailed step-by-step sets of directions (called programs or *software*). A modern computer system is designed to work with both words and numbers—that is, with letters and punctuation marks as well as with digits and mathematical operations.

Every computer system has provisions for the input, storage, manipulation and output of alphabetic and numeric symbols. Every computer system can automatically, rapidly and accurately carry out the steps in a computer program, making use of its input, storage, manipulation and output facilities.

Most machines are designed for a specific purpose. A pencil sharpener sharpens pencils. A lawn mower cuts grass. An automobile transports people along the ground. But a computer is different—it is a versatile, multi-purpose and easily changed machine. Like the aforementioned machines, a computer is comprised of physical machinery, but it is also comprised of detailed step-by-step sets of directions that are carried out by the hardware and which tell the hardware what to do. These sets of directions are called computer programs, or software.

It is software that makes a computer into a versatile and easily-altered machine. At one moment a computer may be a business data-processing machine, preparing bills, doing

the various parts. Once we were safely to the car, we found that there was no secure way to situate all the equipment in a 1973 Volkswagen bug. I drove carefully, and Computer Kid held on. Nevertheless, the computer part tumbled off the seat to the floor as I braked to avoid hitting what, according to my calculations, an inventory or printing payroll checks. A few minutes later the same hardware may be controlling automated factory machinery or determining a likely spot to drill an oil well. Shortly thereafter the hardware may be used to teach reading or arithmetic to children.

The diagram given in Figure 1 lists the main hardware and software components of a computer. This and the following section discuss hardware and software in more detail and explain some of the technical vocabulary of the computer field.

COMPUTER

Hardware	**Software**
Input	Operating Systems
Storage	Language Translators
Manipulation (Central Processing Unit)	Application Programs
Output	

Figure 1: Computer hardware and software components.

To increase your insight into computers, we will discuss two machines with which you are probably familiar: the handheld calculator and the electric typewriter. A calculator has many computer-like features; indeed, it may be thought of as a special-purpose computer. An electric typewriter can have features added to make it more computer-like. Such a computerized typewriter is called a word processing system.

A 4-function handheld calculator is an electronic digital computing device. Its circuitry uses the same types of electronic components used to make a general-purpose computer. An inexpensive, handheld calculator has many computer-like features. These are listed below and contrasted with a general-purpose computer.

- **Input**

  A calculator key pad contains ten digit keys and other keys needed to specify arithmetic calculations.

  [Contrast this with a general-purpose computer, which has provisions for the input of all characters found on an ordinary typewriter keyboard. The computer works equally well with alphabetic and numeric characters. A computer is a useful tool for a journalist as well as for a mathematician.

  A computer may also obtain input from measuring devices such as a thermometer or pressure gauge. Voice input to computers is growing in use. Other input devices such as a touch panel, light pen and graphics tablet are often useful in educational settings.]

- **Storage**

  Consider how a calculator must function as it handles an input such as

$$372.7 \times 580.4 =$$

The calculator must store the two numbers and the operation as they are keyed in until the = key is depressed. That keystroke instructs the calculator circuitry to carry out the (stored) operation on the two (stored) numbers.

[Contrast this with a general-purpose computer. The computer can store thousands of words and numbers. These may be both data to be manipulated and programs that direct the manipulation. For example, the data may be the academic records of all students in a school. The program may compute each student's grade point average and then order the students from highest to lowest grade point average. The computer can then print out this ordered list of students and their academic records.]

was an $800 sparrow.

At home I flipped through one of the manuals while trying to decide which wire connected to which part and was about to attempt the hook-up when I realized that Computer Kid already had the machine operating, therefore not only verifying that I was truly

- **Manipulation**

  The calculator can automatically carry out any of the four manipulations we call addition, subtraction, multiplication and division. More expensive calculators may have additional built-in functions, and thus have a larger repertoire of manipulations they can perform on numbers.

  [Contrast this with a general-purpose computer, whose central processing unit has a built-in instruction set of perhaps 60 to 300 different operations. These are designed for both arithmetic operations and for manipulation of letters and words. Moreover, a general-purpose computer can store and carry out programs that are many hundreds or thousands of individual machine operations in length. Finally, a computer is thousands of times as fast as a calculator in carrying out its built-in operations. Indeed, the fastest computers currently being produced can perform arithmetic about ten million times as fast as a simple hand-held calculator.]

- **Output**

  The numerical output from a calculator is usually shown on a one line screen display or printed by a paper tape printing mechanism.

  [Contrast this with a computer, whose output display may be a high speed typewriter printing mechanism, a television-like display screen or a graphics plotting device. Voice and music output are also common. Still another form of computer output is electrical signals that control devices such as automated factory machinery and space ships.]

In summary, a simple 4-function calculator can be viewed as a special-purpose computer. It has all of the features of a general-purpose computer, but each of these features is limited in scope. It is quite impressive that such sophisticated technology can be mass produced and that good quality calculators can be purchased for under $10.

Almost all adults in the United States have easy access to a calculator. A calculator is easy to learn to use and to operate. When was the last time you used pencil and paper to carry out a long division problem such as 85,927 divided by 482? If you encountered such a problem, you would probably do as most adults now do. You would look for a calculator.

When handheld calculators first began to be mass produced, they were quite expensive. Nobody imagined that they would decrease in price and become a common household item so rapidly. Now the same thing is happening with computers. The rapid decrease in price has been coupled with an increase in quality and ease of use. You may know someone who already owns a home computer.

Next, let's look at an electric typewriter and consider how to make it more computer-like. First, a typewriter can be improved by adding a one-line screen display and one line of internal memory much as you find in a calculator. With this feature a line can be displayed as it is being typed, before printing it on paper. Errors can be corrected by back spacing and retyping. After a line is correctly typed, the carriage return signals the machine to print it on the output page while the typist begins the next line of typing.

But why stop with a single line display and a single line of internal storage? How about a full-page display screen and dozens of pages of internal storage? An entire page can be viewed for editing and correcting before printing it on paper. Whole sentences and paragraphs can be stored, moved about and manipulated as needed. Form letters can be used in a "fill in the blanks" mode to produce nicely typed letters in quick response to frequently occurring situations.

inept at this sort of thing, but also that computers could survive my driving.

My first time alone with the computer came after two and one half hours of such exciting (to a fifth grader) computer work as at least 1000 lines of "This is punishing!" and a Dungeons and

And why stop there? Let's add a large dictionary and provisions for the computerized typewriter to automatically check spelling or aid the typist by displaying a definition. Let's add a proportional spacing feature, so that printed output can have both the left and right margins aligned. Let's add the ability to accept rows and columns of numbers, and to sum these rows and columns automatically on demand.

Finally, let's add provisions to communicate with other word processing systems via telephone lines. Such electronic mail allows messages to be rapidly distributed to receiving stations throughout the world. Now we have a modern word processing system--a computerized typewriter. A *word processor* is a versatile and useful tool. It is a special-purpose computer, designed for office automation. It is a very useful tool to students and to other people who need to do a significant amount of writing.

The distinction between a general-purpose computer and a special or limited-purpose computer is important. Most new cars contain special-purpose computers. Special-purpose computers may be used in home thermostats, microwave ovens, television tuners, clock radios or in home video-arcade games. These special-purpose computers lack the versatility and wide range of applications of the general-purpose computer.

It is particularly important to distinguish between special-purpose and general-purpose computers if you are going to purchase a computer for home use. You might think that a home arcade game computer can also be used as a word processor or to help do your income taxes. Unfortunately, that is incorrect. The general-purpose computer usually costs more than a home arcade game computer, but has considerably greater potential.

For the remainder of this booklet we will use the word "computer" to refer to a general-purpose computer. This means that it has input and output devices equivalent to an electric typewriter. It has substantial internal storage for storing programs and data. It has great speed and versatility. It is able to work with letters and digits, words and numbers. It is a general-purpose aid to problem solving.

This section concludes with a brief history of important changes in computer systems since 1945. It will give you a feeling for how rapidly the computer field is changing. The next section of this booklet contains a more technical discussion of computer hardware and software, providing a different sort of answer to, "What is a computer?"

The first general-purpose electronic digital computer built in the United States became operational in December, 1945. It contained 18,000 vacuum tubes, filled a large room, used an enormous amount of electricity and wasn't very reliable. Setting up the machine to work on a particular problem sometimes took a week or more. It was seldom that the machine functioned for more than a few hours without failure. The vacuum tubes generated a great amount of heat and often burned out.

Computers became commercially available in 1951 when the UNIVAC I went on sale at a price of well over a million dollars. But the vacuum tube machines of the 1950s continued to be relatively unreliable, difficult to use, single-user-at-a-time machines. Most were sold to big businesses, governments and large research organizations. Computers remained too expensive for use in most universities, much less for use at the precollege level.

Three developments changed all this. First came the transistor, invented in 1947. By 1959 it was inexpensive enough to replace vacuum tubes in computers. Because transistors are smaller, generate less heat and are much more reliable, their development enabled a computer to fit into a small room and reduce air conditioning requirements.

The second major development was *timeshared computing*. Computer hardware and software were designed to allow a number of simultaneous users, with each user having good interaction with the machine as it solved the

Dragons quiz on Heraldry that nobody knew how to answer. After my husband and I learned that a boss is a fitting for a Persian shield and other such valuable information, the computer was mine.

"I'm going to learn how to use this machine so I can help you

users' problems. Computer users could communicate with each other through the computer circuitry—an idea similar to that used in our telephone system. The programming language *BASIC* was developed at Dartmouth College especially for student-oriented interactive computing. Since a single large computer could be used simultaneously by a number of people, the cost per user was greatly reduced.

The third major development was the *integrated circuit*. In the early 1960s, people discovered how to manufacture a circuit containing dozens or even hundreds of transistors and interconnecting electronic components. This was called a *chip* due to the small piece (chip) of silicon used as a major part of the integrated circuit. The cost of manufacturing a chip is nearly independent of the number of electronic components it contains, because the same steps must be carried out whether the chip contains 5,000 or 50,000 components. Thus, the cost of computer circuitry decreased quite rapidly.

Progress in chip technology greatly increased the reliability of computers while continuing to decrease their cost and size. When chip technology was applied to calculators, the result was a handheld machine. A decade later some $10 handheld calculators had more capability than a $1,500 electromechanical desk-top calculator of the 1960s.

In 1975 it became possible to manufacture an entire computer using just a small handful of chips for the major part of the electronic circuitry. This new type of computer was called a *microcomputer*, or personal computer, to distinguish it from larger, more expensive machines. Suddenly it became possible for a person to own a computer for use at home or in a small business. Schools at all levels could now afford to own computers.

Progress in chip technology has continued unabated. In 1981 a single chip containing 450,000 active elements was produced. This chip, about the size of an adult's fingernail, can serve as the central processing unit for a very powerful computer. (Remember, the first general-purpose electronic digital computer contained only 18,000 vacuum tubes. Now, a single chip may provide more capability than 18,000 vacuum tubes.) Other chips, now in mass production, serve as memory and as input/output interface circuitry. This progress in chip technology has made possible desk-top computers with far more power than the million dollar, room-sized computers of the 1950s. Roughly speaking, the cost of a given amount of computer capability has decreased by a factor of 100 over the past 20 years, and a similar rate of decrease seems likely to occur over the next 20 years.

In the early 1980s, we now have complete handheld computers costing well under $200. We have desk-top computers ranging in price from $100 (not counting the price of a television set display screen) to $10,000 or more. We have still larger computers, some which fill a large room, with prices ranging up to $15 million. It is the handheld and desk-top microcomputers that are coming into schools and people's homes. These are relatively inexpensive and reliable, and yet have considerable capability.

Microcomputers of the late 1970s were designed to provide interactive computing to one user at a time. Now it is possible to build relatively inexpensive timeshared microcomputer systems. These provide the cheap computer access of single user microcomputers, but with the telecommunication facilities and other advantages of large timeshared systems. During the 1980s such timeshared systems will play an increasingly important role in education. The "School of the Future" illustrated earlier in this booklet makes use of a timeshared microcomputer system.

Projecting a few years into the future, it seems likely that most homes that are now equipped with a telephone and a television set will have a computer. The computer may be built into the television set or may be part of the telephone equipment, in either case probably being used for a variety of educational, recreational and business purposes.

with your computer work," I announced to my doubtful son, who thought he knew all there was to know about computers.

"If you need me," said my husband, "I'll be outside pruning bushes."

"I'll help, Dad," my son said. "Please don't break the com-

PART IV — COMPUTER HARDWARE AND SOFTWARE

Complete general-purpose computer systems range in price from a few hundred to many millions of dollars. Obviously there is a considerable difference between a $200 handheld calculator-like computer and a $15 million computer system. While the most visible differences are in the hardware, software now constitutes a substantial part of the cost of a computer system. Indeed, in many applications, software is now the dominant cost in using a computer to help solve problems.

Perhaps you have been involved in the purchase of a stereo or a major appliance such as a stove or refrigerator. While these are items that you have seen and used for many years, it is still difficult to look at the variety of makes and models and try to decide what best fits your needs and pocketbook.

Likely you would find that purchasing a new car is even more difficult. Currently, new cars range in price from about $5,000 to perhaps $125,000. All cars are alike in that they have a steering mechanism, wheels, seats, a body, a propulsion system, and so on. But cars differ considerably, and the range of prices and features makes selecting one quite difficult.

The most inexpensive, self-contained, handheld computer currently costs about $150, while the most expensive large-scale computer system currently costs about $15

puter, Mom."

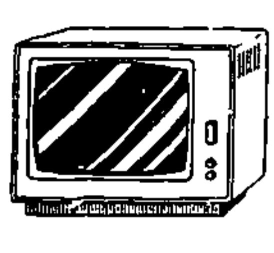
With those words of encouragement, they both were gone. More determined than ever, I sat down in front of the computer feeling very avant-garde, and most professional.

First, I decided to try printing words and sentences as I had million. While an expensive car costs twenty-five times as much as an inexpensive one, an expensive computer costs a hundred thousand times as much as an inexpensive one! This price range seems overwhelming, especially when you consider that most people have not grown up with computers and are not familiar with their use. You can see that the selection of a computer system can be a very difficult task.

The purpose of this section is to acquaint you with some of the hardware and software features that are available in modern computer systems. You will need this information if you are to be involved in evaluating computer systems for use in your home or in schools.

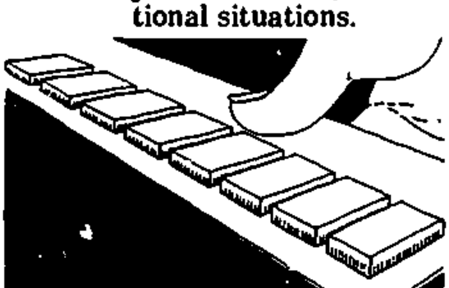
We begin with hardware. Every general-purpose computer system has five major components:

Input Unit
Used to get information into a computer. An electric typewriter device called a keyboard terminal is common.



Output Unit
Used to get information out of a computer. While the most common output unit is a television display screen, a typewriter-like printer is also widely used and is very important in many educational situations.

Internal Memory
Storage space for a detailed step-by-step set of directions and the data that are being processed by the computer. Internal memory must operate at the same very high speed as the central processing unit.

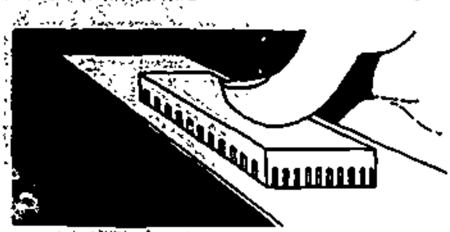


External Memory

Permanent, relatively inexpensive bulk storage for large quantities of data and collections of programs. External memory generally makes use of magnetic tape or magnetic disks. However, small amounts of external storage are provided by plug-in cartridges. A cartridge may contain several games or other programs. When plugged into a slot in the computer, a cartridge becomes part of the internal storage of the machine.

Central Processing Unit (CPU)

Circuitry that decodes the meaning of the instructions in a program and carries out these instructions.



To help you understand why computer systems have such a wide variance in price, each of the main hardware components will be discussed in more detail.

The least expensive computer systems use a calculator-style keyboard for input. Such a keyboard does not allow for touch typing and is frustrating to a skilled typist. A high quality, typewriter-style keyboard adds substantially to the cost of a keyboard terminal. Indeed, the keyboard may cost more than the CPU and internal memory of an inexpensive microcomputer system.

seen Computer Kid do. This, I thought, required only the typing of the word PRINT and then what I wanted printed within quotation marks. I knew I could do that simple process, but just as I was about to type in my premier program, I noticed that the computer had no power. The little red power light on top of the keyboard

There are many other types of *input units* such as a card reader (to read punched cards), optical scanner (to read mark sense scan sheets or typewritten materials), hand controller and joy stick (used in computerized arcade games as well as in many educational applications), touch panel or light pen (input by touching or drawing on the display screen), graphics tablet (for detailed drawing and engineering design work), and voice input (especially useful for people who are unable to use a keyboard). Each of these input devices ranges in price from a few hundred to a few thousand dollars. Each requires special circuitry to connect it to the rest of the computer system. Finally, each requires special software—that is, special programs, to make it functional.

Now you begin to see the complexity of a hardware system. Should one be thinking about attaching a thousand dollar graphics tablet to a computer system whose base sticker price is only $500? What are the capabilities and limitations of voice input, and what does it cost to develop software suited to a voice input system? Is a graphics tablet more useful than a light pen for doing engineering or architectural drawings?

Output systems are almost as diverse. A handheld computer may have a single line display, just like a handheld calculator. Adding a printing mechanism may double the cost of a handheld computer system.

A plotter is a versatile and useful output device. With it one can print out graphs, charts and line drawings. More expensive systems can automatically change the pen being used, allowing for multicolor output. But a plotter can easily cost more than an inexpensive microcomputer system.

High speed printers come in a wide variety of price ranges, quality and capability. At the top end of the scale one might pay over a hundred thousand dollars for a device that can print 20,000 lines per minute. Such a device could print out a copy of this booklet in a few seconds. At the other end of the scale, an inexpensive printer costs about the same as a medium-priced electric typewriter. Printers cheaper than that tend not to stand up well under heavy use and can be quite expensive to maintain or repair.

Voice and music output are now quite common. Many computer systems have a built-in tone generator. Roughly speaking, this permits the computer to output music with a quality similar to a one-fingered piano player. This is called a one-voice tone generator. Some microcomputers now contain better tone generators, able to play several tones simultaneously.

A still more sophisticated and higher quality music or voice synthesizer can add many hundreds or thousands of dollars to the cost of a microcomputer system. Such equipment can be used for ear training and musical composition instruction.

The *internal memory* of a computer system holds the program being executed and data as it is being processed. This memory must function at a high speed. An inexpensive computer system is apt to have a very small internal memory, perhaps one capable of storing a few thousand letters and digits. At the other end of the scale, a very large computer system will have internal memory storing millions of characters. Such a computer can effectively deal with programs that are tens of thousands of instructions in length.

Many computers are designed so the size of their internal memory can easily be increased. This may be accomplished by inserting an additional circuit board into the computer or plugging in a cartridge. As previously mentioned, such a cartridge may contain a program for a game or a program to solve a particular type of problem.

External memory for most computer systems is some form of magnetic tape and/or magnetic disk. Computer programs and data can be stored on a magnetic tape, much like the cassette tapes commonly used to record and store voice or music. Indeed, a cassette tape recorder is often used for this purpose on inexpensive microcomputer

was out and nothing happened when I pressed the keys. The electric plugs—all three of them—were in the sockets, but the machine was dead.

That was the beginning of the end of my professional mien. I took off my sweater to get a bit more comfortable, poured a cup of systems. But cassette tape systems are relatively slow (it may take several minutes to store or retrieve a program) and not very reliable (programs and data are sometimes lost when a tape system fails to function properly).

A magnetic disk is essentially magnetic tape spread out flat on a rotating disk. The read/write mechanism can be positioned over any spot on the disk in less than a second. This means that programs and data can be stored or retrieved in a few seconds. If the disk is made of flexible plastic it is called a *floppy disk*. If the disk is made of rigid metal it is called a *hard disk*. A floppy disk capable of holding more than the contents of this booklet costs about $3. But the *disk drive*, the hardware that reads from and writes to the disk, costs several hundred dollars. A hard disk system is still more expensive, with the cheapest costing approximately $2,000. However, such a hard disk can store the equivalent of a number of very thick novels—that is, millions of characters.

Large computer systems usually have both high quality tape drives and hard disk drives. An insurance company or a bank wants to have all of its customer information readily accessible. Such companies may have billions of characters of disk storage connected to their computer systems. Such large storage systems are capable of storing a set of encyclopedias and thousands of other reference books. Terry, for example, made use of an on-line encyclopedia stored on a hard disk system.

Finally, we have the *central processing unit*. CPUs vary greatly in speed and capability. The most expensive computer systems are more than a thousand times as fast as a typical microcomputer. Suppose, for example, that one is using a computer to do weather forecasting. Perhaps a week-ahead forecast takes a full 24 hours of computation on the world's fastest computer system. The same problem would take years to solve using a microcomputer system.

It is software that gives a computer system its versatility. By the use of different software, the same hardware can solve problems in business, government, research or education.

Software is a detailed, step-by-step set of directions that can be automatically carried out by hardware. You have seen detailed directions in non-computer fields. A cook's recipe is a detailed set of directions, as is a musical score. A sewing pattern and a carpenter's blueprint both provide detailed directions. In all cases humans read and interpret the directions, adding human qualities as they follow the directions.

A player piano or a music box is more computer-like than a recipe or a musical score. Now the machine contains both the detailed directions and the capability of carrying out those directions. A player piano can have a large library of musical pieces, much as a computer system can have a large library of programs.

There are two key ideas that you should learn about software. First, most software is difficult to create. Second, software designed to run on one computer system may not be usable on another computer make or model. We will discuss each of these ideas further.

Suppose that a programmer/analyst is faced by a new problem that might be solved by computer. The person first analyzes the problem and seeks to determine if someone has already written a program for its solution. Let's assume that no such program is available.

coffee to help me restore my avant-garde image, and then searched for a possible on/off switch—all the while simply refusing to consult an instruction manual to find something so trivial.

After examining each key without success, I reconsidered the triviality of "manual" guidance on this matter, only to read that

The programmer/analyst will then carry out the following sequence of steps:

1. **Understanding the problem.**
   What is known, and what is to be accomplished? This requires knowledge of the problem area as well as good communications skills to work with the people who want the problem solved. Good library research skills will probably be required to find out what other people have done when faced by similar problems.

2. **Developing a plan for solving the problem.**
   This plan takes into consideration the collection, storage and retrieval of the data needed to solve the problem. It includes the development of a procedure (a detailed step-by-step set of plans) to solve the problem. This step requires good analytical and creative skills plus considerable knowledge of the capabilities and limitations of computers.

3. **Writing the computer program, entering it into the computer and testing it to verify that it correctly solves the problem.**
   This requires good programming skills and intimate knowledge of the computer system to be used. It requires a systematic and logical mind.

4. **Completing documentation of the overall problem-solving and programming task.**
   If the program is to be used at a later date, this includes writing detailed directions for its use. Good writing skills are required.

It is true that students can learn to write simple computer programs after a few minutes or a few hours of instruction. But many thousands of hours of training and experience are required to develop a reasonable level of expertise as a programmer/analyst. Often this requires a four year college degree in computer science or a related field, plus several years of experience. For this reason, programmer/analysts are in short supply and great demand. The pay for such people tends to be relatively high.

It is helpful to look at a specific problem-solving example. Suppose that a school system wants some computer programs that would be useful in helping learning disabled students learn to read. The typical programmer/analyst knows little or nothing about learning disabled students nor about teaching reading. The programmer/analyst is probably unfamiliar with current educational research in learning theory or other related topics.

A partial solution is to put together a team of people, perhaps consisting of a reading specialist, a master teacher specializing in work with learning disabled students, a graphic artist and a programmer/analyst. After these people learn to work together they are apt to be able to develop some useful software. The software will need to be classroom tested, however, and will need to go through several revision cycles. It may take many hundreds of hours to produce a piece of software that occupies a student for an hour.

Now you can see why good educational software is expensive and why it is not readily available. Relatively few companies can afford to fund such development projects, and federal or state funding for such projects seldom occurs. Likewise, few school systems can afford to allocate money for the development of high quality educational software.

The software transportability problem adds yet another dimension to the development of high quality educational software. Suppose that we manage to secure funding to develop some good software to help learning disabled students. What computer should we use for the project? We can attempt to develop software that is independent of the specific details of any particular machine. We will find that this is nearly impossible, and that it is quite restrictive. For example, we might want to use graphics (pictures) as part of the output in our software. But details for computer graphics vary widely among computer systems. Or, we might want to use a touch panel input and voice output.

the evasive button was on the back of the computer next to the power jack. If I had known what a power jack was, I would have been in great shape, but since I didn't, I looked for the back which I assumed would be in back of the front. It wasn't. I soon realized that what I called the back of the front was really the bot-

Again, it is a situation where no national standards exist.

It is likely that we will do as others have done. We will pick one of the popular microcomputers and develop our software specifically for it. But, we will try to do our design work so that our program can easily be rewritten for other computers. Most companies that produce educational software take this approach. They have versions of their software to fit each of the widely sold microcomputers.

Over the long run we can expect considerable progress in the standardization of computer systems, so that software developed for one system will run on many other systems. We can also expect continued rapid progress in the computer capabilities that can be purchased for a given amount of money. The combination of these two factors will insure that computers will become increasingly useful as an educational tool at school, at home, and on-the-job in other educational situations.

Over the next decade, educational software will continue to be a major problem. Although hundreds of companies now produce educational software, the quantity that would be needed to cover an entire curriculum is immense. For many years to come, books and other conventional instructional materials will remain as the dominant aids to learning.

PART V — COMPUTERS IN EDUCATION

In this section we examine computers in precollege education. Computers have many administrative uses such as keeping student records, doing accounting and payroll work and class scheduling. But our main emphasis is upon instructional uses of computers. Computer assisted learning deals with all aspects of using a computer to help students learn. Other instructional aspects of computers include studying how computers affect the content of each non-computer academic subject, and studying computer and information science as a subject in its own right.

Education is a big business. A typical public school system operates on a budget of perhaps $3,000 or more per pupil per year. This money is used for clerks and secretaries, custodians and maintenance personnel, teachers and curriculum specialists, athletic coaches and administrators. A school system owns buildings, furniture, teaching equipment and supplies. It maintains records on its personnel and its pupils.

One can divide educational uses of computer into two main categories. One category is non-instructional. Applications such as payroll, accounting, ordering, inventory and record-keeping are quite similar to those found in any large business. A second category is instructional. While the main part of this section deals with instructional uses of computers, we will first discuss some non-instructional applications.

tom of the top and the real back was just over the keyboard edge on what seemed to me to be the top of the bottom.

Nevertheless, I pressed the button and the power came on, along with a display which looked like an advertisement for a shoe company. Filling the video screen were about 500 letter A's wip-

The computer industry grew very rapidly during the 1950s and 1960s as computers became commonplace in big business and in government. A typical application is in the personnel/payroll office, where it is necessary to keep detailed records for each employee. These records are used to produce payroll, tax reports, cost analysis reports, vacation schedules, and so on. Computers can be quite cost effective at these tasks.

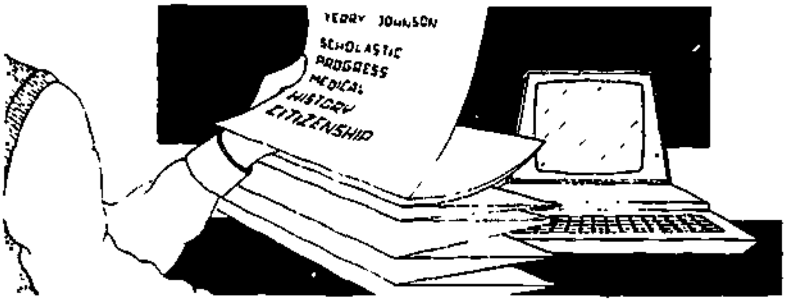
It is not surprising that as computer use grew in business and government, it also grew in education. Certainly the personnel/payroll problems are similar. But schools have another administrative problem. It is necessary to keep detailed records on students. Attendance records are used to produce state government reports necessary to obtain state funding. Course and grade records are needed to track a student's progress toward graduation. Competency tests and other types of exam records are collected over a period of years and are an important part of a student's record.

A computer system that can be used for personnel/payroll records can also be used for student records. Certainly the student record problem is larger and slightly more complex, but it is the same general type of problem.

Or is it? Suppose that an error occurs in entering data into a student record. Perhaps a student's score on an important placement test is recorded as 79 instead of 97. This score might be used several months later to place the student into a particular class. A score of 79 might be considerably below average, causing the student to be classified as below average and to be placed in a remedial education situation. A student's whole educational career might be altered by a single error of this sort.

Consider another problem. Who has access to these detailed student records? Before the age of computers, the records were kept in a locked filing cabinet, with access to such records controlled by school personnel. Computerization of the records may make them accessible to unauthorized personnel such as computer operators. Indeed, if the computer is a timeshared system, it is possible that some enterprising student may break into the system to read and perhaps change records.

The two situations we have described are typical of problems that can occur with the non-instructional use of computers. If you have children in school you may want to find out if their records are computerized. If they are, what provisions exist for checking the accuracy of the records and for correcting errors? Who has access to these records, and for what purposes? What happens to these records after the student leaves school? A responsible school system will be able to give you satisfactory answers to all of these questions.



For the remainder of this section we will focus on instructional uses of computers. As with non-instructional uses, there are both appropriate and inappropriate uses. Three main instructional uses of computers are:

1. **Computer-Assisted Learning.**
   Here the computer directly affects the teaching/learning process.

2. **Computers and Problem Solving.**
   Computers are both an aid to problem solving and a source of problems in every academic field.

3. **Computer Literacy.**
   What can students learn about computers and computer science, and what should they learn at various educational levels?

ing themselves out one by one. Whatever it was was impressive, but it wasn't what was supposed to be there. While I was looking for the little unassuming word READY which the manual said would appear, A's flashed off madly. I waited while they attempted to destroy themselves, hoping they would all disintegrate and

Our visit to the School of the Future illustrated the promise of Computer-Assisted Learning (CAL). Terry used reading skills to interact with a computer to learn about history, geography and arithmetic. Terry used a computer as an aid to information retrieval and as a writing tool. The computer kept records on Terry's performance and helped communicate Terry's work to the teacher.

While all of these things are possible, some are more easily accomplished than others. The easiest and most mundane instructional use of computers is for *drill and practice.* A student sits at a computer terminal, reads a question and types a response. The computer provides feedback on the correctness of the answer, updates the student's record and goes on to the next question. At the end of a session the computer outputs a report to the student and updates the teacher's records.

Drill and practice is an important part of education. Teachers drill students both in group and in one-on-one situations. Workbooks drill students. Students use flashcards to drill themselves and each other. Teaching machines and handheld calculator-like machines drill students. Adding one more method of drilling students will not in itself revolutionize education.

But even in computerized drill and practice we can see the appeal of computers. The computerized drill allows students to work at their own rate. Each student can work on drill materials suited to his or her specific needs. Feedback can be immediate. A sophisticated drill and practice program can analyze student response patterns and make appropriate changes in the material being presented.

A more sophisticated form of CAL is *Programmed Instruction* (PI). Here the computer contains material to be presented to a student. A common format is to present a small amount of instruction and then ask the student a question. Depending on the answer, the computer may present more instruction on the same topic or move on to another topic. Programmed instruction can be an effective aid to student learning. It can provide a particular kind of individualized instruction. Certainly it provides immediate feedback and tends to keep a student on task. A motivated student who already knows part of the material or who is a quick learner may progress quite rapidly. Other students may get bogged down, essentially going over the same material day after day. They may need considerable help from a (human) teacher.

Programmed instruction is a useful educational tool. However, many programmed instruction materials currently being used in education are both uninteresting and of relatively poor quality. This isn't surprising, considering the difficulty of developing high quality programs and the newness of microcomputers. Thus, PI is just one additional aid to teachers and students, and is *not* a solution to every instructional program.

As with drill and practice, there are alternative ways to help students learn. Merely using a computer to present programmed instruction materials does not guarantee that a particular student will learn more, or better, or faster. Students vary widely in what best helps them learn. The role of teachers remains clear. They need to interact closely with students, guaranteeing the flexibility of the overall educational program and providing the all-important human element.

Over the past twenty years there have been hundreds of research studies on the use of computerized drill and practice and programmed instruction materials. Initially, the results tended to be inconclusive. Some students did learn faster or better, while others showed no significant gains as compared with conventional modes of instruction. Since CAL tended to be quite expensive, such studies did little to justify an extensive introduction of computers into ordinary school settings. However, such studies did tend to justify the use of computers in special education and in other settings where conventional education is quite expensive.

READY would magically appear.

Since it didn't, I turned the computer off using the well-hidden button and then pressed it on again. No A's. Just words at the top of the screen asking what memory size the computer was. Why this computer did not know how large its own memory was I

In recent years, a pattern of greater success has emerged. Computerized instructional materials are getting better as developers gain insight into effective use of this new instructional medium, and this progress can be expected to continue. There will be continued and rapid growth in the amount and variety of CAL instructional materials. And since computers are continuing to decrease in price, we can expect a rapid increase in CAL usage.

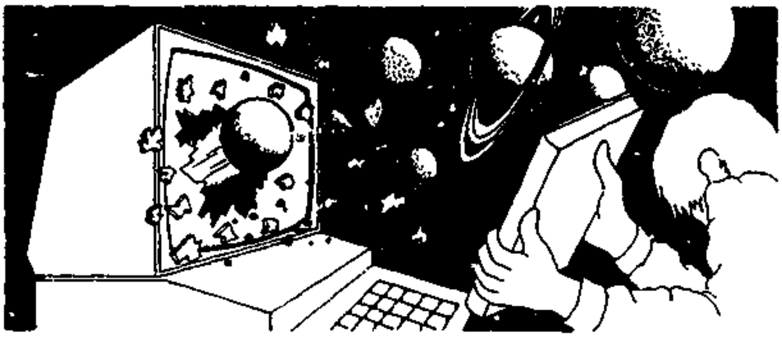
If one were to give a very short statement on the goals of education, the response might be, "To help students learn some facts and to help students learn to think using those facts." Drill and practice is well suited to helping students learn some facts. Many programmed instruction materials have a similar goal. There are other forms of CAL, however, that endeavor to improve a student's thinking skills. Such educational materials can put students into thinking and problem-solving situations and can interact with students as they deal with a variety of non-routine problems.

Educational simulations is one category of more sophisticated instructional materials. For example, there are computer programs that simulate the operation of a nuclear power plant. A student can learn to run the plant, monitor the controls, assessing it for safety and making decisions when emergencies arise. Or, one can become immersed in a simulation of history, perhaps being the ruler of a country over a period of years. This is not too different from the Marco Polo simulation that Terry was using earlier in this booklet.

A high-quality, realistic simulation can be an excellent aid to education. It allows the student to rapidly gain experience in a situation that may be impossible or impractical to duplicate through conventional educational aids. But the development of a simulation is a difficult task, and relatively few good ones are currently available.

A simulation need not be that of a "real world" situation. One can simulate being a space pilot, even piloting a faster-than-light ship. One can simulate traveling into a world of dragons, elves and trolls. Such imaginary worlds have great appeal to many children. They will play such simulation-games hour after hour. Parents who worry about their children spending time on such activities might remember back to their own childhood, and the many hours spent playing games such as Monopoly and Old Maid. Some of the new simulation/games are both more entertaining and more educational than many of the "traditional" games of the past.

This is an important point. It is quite appropriate that schools make use of educational simulations. These may include simulation/games, designed to help students learn certain ideas through absorbing activities. The line between educational simulation games and "pure entertainment" simulation/games is not clearcut, but some simulations clearly have limited education value. Most zap-the-invaders games seem to provide little more than eye-hand coordination practice and an opportunity to work off frustrations. It may be best to restrict time spent on some simulations, just as one restricts desserts.



From the beginning of this booklet we have stressed that computers are a new, general-purpose aid to problem solving. In summarizing the main steps in problem solving, we can see where computers fit in. Suppose that one is faced by a relatively hard and unfamiliar problem situation. The standard steps to follow are listed below. As you read them, look back at the steps a programmer/analyst follows in solving a problem using a computer (p. 30).

could not guess. So I guessed at the size. BIG, I typed. ERROR the machine replied. MEDIUM, I typed. ERROR. SMALL, I typed. Another ERROR. Still no READY. I was READY, however, at that moment, to take the easy way out by ending my short and unsuccessful journey into the Computer Age. A voice in my brain sug-

1. **Understanding the problem.**

   Here one draws upon one's total knowledge and experience. Most problems are interdisciplinary in nature, so the broader one's knowledge and experience the better.

2. **Finding or developing a solution procedure.**

   This may involve library research, talking with experts in a variety of fields and extensive study of the problem. Developing solution procedures is a thinking process. It draws upon one's total knowledge and experience.

3. **Carrying out the solution procedure.**

   This may involve extensive collection and manipulation of data. Often this is a routine task, requiring accuracy and patience.

4. **Examining the final results—the "solved" problem.**

   Do the results make sense? Has the problem actually been solved? Once again thi is a thinking process, drawing upon one's total knowledge and experience

If the problem to be solved is relatively simple, one may go through all of these steps in a few seconds. More often, however, the overall process requires considerable trial and error. If a problem is sufficiently complex, the whole process may take years.

We can examine these steps in light of our current educational system and in light of the capabilities of computers. A great deal of time in school is spent on reading, writing and arithmetic. The role of reading in problem solving is apparent—reading gives one access to accumulated knowledge found in libraries. The role of writing is also clear—writing helps one organize thoughts and communicate plans and results. Arithmetic is used to work with situations that can be represented by numbers—things that can be measured or counted.

Quite a bit of school time is spent in memorizing facts. Here we need a balance between what students carry around in their heads and what they know can be retrieved from a dictionary, encyclopedia or other reference books. Finally, much school time is spent developing speed, accuracy and neatness at carrying out routine tasks. Arithmetic is to be done neatly, accurately and rapidly. Handwriting is to be done neatly, with no errors in spelling and punctuation. In both of these examples, a computer can be an excellent aid.

What tends to get short-changed in our educational system is thinking! We spend so much time on the basics of education that little is left over for the overall, higher-level tasks involved in problem solving.

Computers can affect this in two ways. First, computers can help people learn more quickly, and they can provide faster or more convenient access to information. CAL can make a significant difference, as can computerized information retrieval. Word processing can aid in writing, revising and producing a clean final copy.

But there is another way that computers can make a substantial difference. What facts should students learn and what routine skills should they develop? What is a good balance between memorizing the spelling and definition of every word in the English language versus memorizing only a fraction of them and learning to use a dictionary? Is it necessary to know how to compute the square root of a number by hand? (Many calculators have a square root key.) How good should one's hand printing and cursive writing skills be? Might learning to type and use a word processing system be more useful than continued practice in developing superior handwriting skills?

These types of questions are only the tip of the iceberg. A computer can do many things that take people days or weeks to learn to do by hand. For example, suppose one is studying population growth and that the problem is to draw a bar graph showing the population of a certain city every ten years from 1900 to 1980. The raw data must be scaled, the bars must be carefully drawn and labeled, often with considerable emphasis placed on neatness. Indeed, so

gested a hasty retreat to the Age of the Cannon, using the excitement of the rockets' red glare to cover the shame of withdrawal. Ignoring the wisdom of the voice, I vowed to go forward, for retreat was just what Computer Kid and Pruner expected me to do.

much effort may be put into the bar-graphing process that little or no time is spent studying why one would want to graph such data, or the meaning of the results. That is, the emphasis is upon routine, low-level processes rather than on higher-level thinking and analysis.

A properly programmed computer can accomplish this bar-graphing task in under a minute. Programs of this sort are readily available, and it takes only a few minutes of instruction and practice to learn to use them. Most likely the bar graph program can also do pie charts, band graphs and line graphs. By using a computer, a student can look at the same data presented in several different ways. In the time needed to do one bar graph by hand, the student might look at several different sets of data and write some conclusions about the best way to graphically represent this type of data.

Or, consider a more mathematical example. In first and second year high school algebra, considerable time is spent in learning to solve certain types of equations. But computer programs exist that can solve such equations easily and quickly in a few seconds. Indeed, one can even purchase calculators that automatically solve an equation. So, what should students learn to do mentally or by using pencil and paper? When should students learn to use calculators and computers?

These are hard questions. Progressive school systems are addressing such questions, as well they should. Instruction in arithmetic calculation versus use of a calculator is an especially difficult situation. Take the example of long division of multi-digit numbers. A study published in the December 1980 issue of *The Arithmetic Teacher* reported that approximately two years of a typical student's math education time in grades one through nine is spent on long division. At the end of this period of instruction, a typical student may be able to divide a three-digit number into a five-digit number in a minute and get a correct answer 85% of the time. A fifth grader can learn to solve the same problem on a calculator after only a few minutes of instruction. Using a calculator one can solve such problems more rapidly and with a higher percentage of correct answers. Perhaps we should drop a year of paper and pencil long division instruction from the curriculum and give every student a calculator. The time saved could be spent studying and practicing higher level problem-solving skills.

Another example is provided by the typical high school business education class. While computers are commonly used in business, few high school business students learn such uses. Instead, they learn traditional, non-computerized methods to deal with business problems. Similarly, the typewriter is rapidly giving way to word processing in the modern business office, but most high schools have yet to introduce word processing into their curricula.

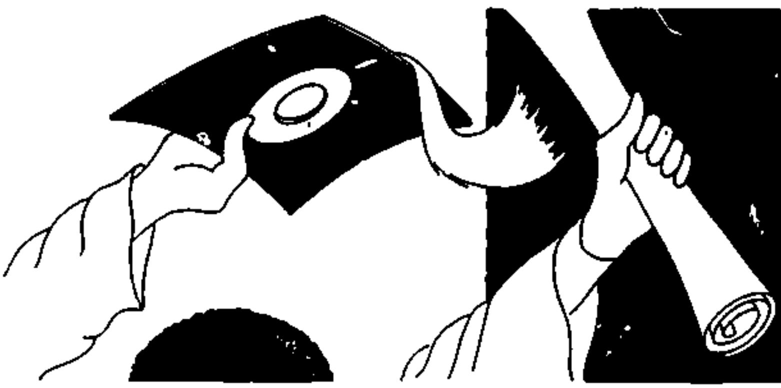
While computers are an aid to problem solving, they are also a source of problems. We mentioned the problem of errors in computerized data and also the problem of controlling access to computerized records. These are important social and ethical problems, certainly suitable for inclusion in a modern curriculum. Closely related is the "big brother is watching you" problem. What data should government agencies keep on people, and who should have access to these files? Should the government keep detailed medical, employment and educational records on all people? Who should have access to tax records, police and FBI records, Social Security and welfare records?

Computers affect curriculum in another way. Art provides a good example. Computers are a new artistic medium. They now play a large role in commercial art, in television and in movies. A computer can serve as an electronic paint brush, allowing a student to rapidly experiment with color and form. Where do students gain access to equipment to learn about this new medium? The typical precollege art course has not been affected by computers.

While I was assuring myself that I was indeed capable of mastering how to turn a computer on, the door slammed and the house rumbled from the delicate footsteps of Computer Kid.

"Great, Mom." he said, looking at the screen. "Terrific program!"

In this booklet we cannot examine each part of the curriculum in detail. But the pattern of our examination should be clear. Computers can help solve problems in every academic area as well as being a source of new problems in many of these areas. This means that the entire curriculum needs to be reexamined in light of computer capabilities and the overall goals of education. Substantial change may be necessary, especially as computers continue to grow in capability and availability.



Earlier we spoke of "computer literacy" and the question of what students might learn about computers. The field of computer and information science is well established at the community college, four year college and university levels. Many high schools now give computer courses, and formal instruction is emerging in some junior high schools.

But the question of what students should be learning has not been resolved. There seem to be three main difficulties. First, the amount of computer hardware available for student use is still quite limited. A ratio of one microcomputer per 100 students now exists in many high schools. Such a ratio provides an average of four minutes of computer time per student per day. Clearly this amount of computer use has little impact on the overall curriculum.

A second major difficulty is software and related instructional materials. Even where hardware is plentiful, software and curriculum materials are currently inadequate. Most current textbooks ignore computers, and almost none attempt to integrate computer-assisted problem solving into the curriculum.

Finally, there is the problem of teacher knowledge. Even with adequate hardware, software and related instructional materials, teacher knowledge is a limiting factor. There is much to learn about computers as an aid to learning and as an aid to problem solving. Most teachers are like you—their formal education ended before computers became important in education. The answer is teacher education—preservice and inservice computers-in-education learning opportunities need to be made available to all teachers.

Assuming that all of the problems listed above can be overcome, realistic goals for computers in education are not too difficult to define. Typical goals are:

1. All students should become functionally computer literate. (Details on the meaning of computer literacy are given later in this section.)
2. Computer Assisted Learning should be used when it is educationally and economically sound. If a modest increase in the cost of education can help students to learn substantially more, better or faster, then certainly we should take advantage of computers.
3. The content of the curriculum at all grade levels should adequately reflect computers as an aid to problem solving and computers as a source of problems.
4. If a school system can afford appropriate computer facilities and staff, then more advanced training in the computer field should be made available both to students who will seek employment upon leaving high school and to those who will go on to college.

The key to these four goals is functional computer literacy. Even a preschool child can learn to turn on a computer system, call up a program at his/her level from a pro-

"I just started," I lied.
He reached over my shoulder and pressed a key called ENTER. Onto the screen came READY. It was as simple as that—for him.
"I'm ready," he said and pulled a chair up alongside mine. "I'm ready to see your work."

gram library, run the program and interact with it for instructional purposes. Thus, all students can benefit from CAL and can learn about this new form of instruction.

An important part of education is learning *about* learning and learning to learn. A computer-literate student is comfortable with CAL, knows when it is useful, and knows how it compares with other aids to learning. Note that such knowledge is highly dependent on both the student and the subject matter under consideration. This knowledge comes through experience and specific instruction about the issue of learning.

Almost all students can learn to use a word processing system. Such a system might have the features Terry used at the School of the Future. Certainly this tool is a useful aid to education in all academic disciplines. Studies have been done on the age at which students can learn to type and to use a word processing system. These studies indicate that learning to use a word processing system can occur simultaneously with learning to read and write. Of course, the studies do not answer the question of whether we want to provide all first graders with word processing equipment. The long term effects of children using word processors will, of course, take many years to determine.

Terry also made use of a computerized information retrieval system. Eventually, such facilities will be commonplace in libraries, schools, businesses and homes. In the same way that students now learn to use a library, eventually all students will learn to use an information retrieval system as well. Instruction in the use of an information retrieval system can begin simultaneously with learning to read and write. Of course, this requires that the system be suited to the needs of young children. Few such systems currently exist.

There are now many hundreds of computer information retrieval systems. An entire encyclopedia is now on-line, as are abstracts of hundreds of thousands of journal articles, stock market quotations, sporting event scores and airline schedules. Telephone companies are experimenting with replacing the telephone directory in people's homes with a computer terminal.

Informal computer instruction can be integrated into education at all levels, but when, if ever, should a student learn to program a computer? Experiments suggest that even preschool students can learn to write simple programs. Many upper elementary school students have learned to program. Many junior high schools offer programming classes, and such instruction is now common in many high schools.

Part of the issue about whether and/or when to teach programming centers around the goals for such instruction. If the goals are merely exposure to the process and the development of quite a low level of skill, then this can be accomplished easily for almost all students. But if the goal is to develop a substantial level of programming skill, then we cannot expect a high percentage of success with current programming languages and methods of instruction. In many colleges, as many as 30-40% of students are not successful in an introductory programming course.

There does not appear to be a simple answer here. The successful teaching of an in-depth knowledge of computer programming depends upon three things:

1. **The student must be developmentally ready.**
   Since programming is a rather high-level form of problem solving, it may well be that few students are ready for serious instruction before the junior high level. Indeed, many college freshmen are not prepared for this type of abstract thinking and problem solving.

2. **Appropriate computer facilities must be available.**
   For example, what programming language should be used? BASIC, the language most readily available, was designed for college students. Logo is certainly much better suited to the needs of young students. Pascal is now the preferred language for college students who are

Ready, I thought, hating the word. How did he know where it was? P-R-I-N-T, I typed, hoping I could remember this part better than how to turn the machine on. Quotation marks, followed by my message. HELLO COMPUTER KID FROM MOM. I finished typing and nothing happened. The modern age was making me potential computer science majors. We can expect that the future will bring still other languages that are better designed to meet the needs of young students.

It is not enough to make computer facilities available just for a computer course. Once students learn to use a computer, they need computer access in all of their subsequent education. It does relatively little good to teach a sixth grader to use a computer if there are no computer facilities in the junior high school the student will attend. Of course, a home computer takes care of this situation.

3. Teacher knowledge.
   Few teachers have had enough training and experience with computer programming to be qualified to teach this subject at an elementary or junior high school level. Would you want a person who "learned" piano in an eight-hour course to be your child's piano teacher? Would you like to have your child learn to drive from a person whose first exposure to a car occurred the previous summer, and who had taken one course on "car driving, with hands-on experience?"

All three of these problems are being overcome at the college level, where enrollment in computer programming courses has expanded very rapidly. But a new trend is emerging at this level. The first college course for students seriously interested in computers is becoming a computer science course, with considerable emphasis on topics other than programming. Computer programming is important, but topics such as problem solving, development and representation of algorithms, computer architecture and discrete mathematics are also important.

This new approach to teaching computer science is also beginning to enter high schools. A detailed course outline for use in high schools by Jean Rogers has been published by the International Council for Computers in Education.

The course outlined by Rogers does include computer programming. However, other major topics include Using Computers for Learning, Information Retrieval, Computers in Creative Arts, Modeling and Simulation and Artificial Intelligence. The goal in this year-long course is for the student to acquire a broad understanding of the field of computer and information science. This is consistent with our educational system's goals for all students: to develop a reasonable level of knowledge and skill in the sciences, social sciences and humanities.

sweat. Women are supposed to perspire—not sweat, but this was definitely a sweaty dilemma. I couldn't ask a ten-year-old what to do next. Bravely, I took a chance and pressed that ENTER key, the same one that produced READY. Instantaneously below my instructions came the beautiful words, HELLO COMPUTER KID

PART VI — WHAT YOU CAN DO

This section discusses a number of things that you can do to help your children and other children learn about computers. Children can learn about computers via their schools and you can help insure that computer education does occur in these schools. You may be interested in computer education at home and the possible purchase of a home computer. Your public library could become a source of computer access and computer instruction, as could a nearby science museum. Some Boy Scout and Girl Scout troops provide computer access and instruction, as do a variety of other young people's organizations. Computer summer camps are now common, as are courses that you can take at a computer store or in other private education settings.

You have already taken a critical first step in helping your children and other children learn about computers. You have added to your knowledge about computers. and especially about computers in education. Now, as you talk with your friends, neighbors and children, you can more comfortably bring up the subject of computers. You can ask their opinion about computers and contribute your own ideas. Ask your children what they know about computers and what they think about computers. You may be surprised at the breadth of their knowledge. At the same time, you may be dismayed at the gaps in their knowledge. This is typical of knowledge gained through informal

FROM MOM. It worked!

"Pretty good," he said patting me on the shoulder. "You're learning."

"How did you know to press ENTER to get READY on the screen?" I asked, feeling confident enough now to admit previous

sources such as television, comic books and talking with one's friends.

You now have a foundation for acquiring more knowledge about computers. Look for television specials on science or computer-related topics. Invariably such programs contain considerable information about computers. Pay attention to newspaper and magazine articles on computers. All of the major news magazines have run feature articles on computers in recent years. *Time* Magazine even selected "Computer" as the 1982 "Man of the Year." Publications such as *Business Week, Forbes,* and *The Wall Street Journal* often contain computer articles. Look at computer hardware and software advertisements. These ads can give you insight into the latest products. The nature of the ads suggests the increasingly large market for computers.

Perhaps you have had a substantial amount of computer training and experience. It is more likely, however, that the amount of hands-on experience you have had with microcomputers is quite limited. An interesting way to help change this, and to put yourself more in tune with today's children, is to visit an electronic arcade. Plan to spend a few dollars. Most of the machines cost twenty-five cents to play, but many arcades use tokens which they sell at five or six for a dollar. Begin by watching children play the various games. Each game is actually a special-purpose microcomputer, specifically designed for entertainment. Notice the quality of the colorful computer graphics and the use of sound. Notice the variety of input buttons and joy sticks. Finally, notice the children and adults as they immerse themselves in this new form of entertainment.

Try out several different games. You are apt to find one that seems more enjoyable than others. Play it a half dozen times and see if your score improves with practice. (But remember, this is a serious educational experience. Take care that you don't have too much fun!)

A computer store is a second source of hands-on experience. Any store that sells microcomputers should be willing to give you a little instruction and a demonstration. Try to arrange to be left alone with a machine, so that you can try out its features without feeling pressured by a salesperson. At this stage, at least, your goal is to learn rather than to purchase. You certainly would not want to purchase a microcomputer until you have tried out several different brands.

A computer store is also a good place to practice your growing knowledge of computers. Ask a clerk if the store carries any educational simulations, indicating that you would like to try one. See if the simulation would fit some of the educational needs of children you know.

A local school is a third source of hands-on experience. The great majority of high schools now have some computer equipment, as do many junior high and elementary schools. Call the school your child attends and ask to talk to the computer teacher. Explain that you are reading a booklet about computers in education and would like to see how computers are used in the school. Indicate that you would like a few minutes of help from the teachers or a student so you can become familiar with the particular computers being used and classes offered in the school.

A fourth possibility is that you know someone who owns a microcomputer. Many people are quite happy to show off their new "toy" and to demonstrate their new knowledge. Check with your neighbors and the parents of your children's friends. You may be surprised at how many of them own a computer.

A fifth possibility is where you, your spouse or a friend works. Millions of microcomputers are now in everyday use in a wide variety of work situations.

ignorance.

"It's in the manual," he answered.

"I don't think it's in this manual," I suggested, showing him the manual I used.

"Of course not," he replied. "This is a Level II Computer and

There are many ways you can help your children and other children learn more about computers:

1. You can help to insure that public and/or private schools in your community, even preschools if your child attends one, provide appropriate computer education.
2. You can work to have the public library and/or science museum in your community provide computer access and instruction. A Parks and Recreation program or a school library might also help provide computer access.
3. You can work to promote computer access and instruction for children in organizations such as Boy Scouts, Girl Scouts, Campfire Girls and 4H.
4. You can send your children to a computer summer camp and/or enroll them in a formal computer course at a computer store, school or science center.
5. You can acquire a computer for you and your children to use at home. (Part VII discusses this topic.)

There is not space in this booklet to discuss each of these five ideas in detail, so we make one very important suggestion: TRUST YOUR OWN COMMON SENSE AND INTUITION. You now know that a computer is merely a machine, a new general-purpose tool. (A pencil is an old general-purpose tool.) Since you are familiar with many other machines and other general educational-type tools, you have a strong foundation upon which to base your common sense.

One of the best ways to demonstrate common sense is to ask questions and to indicate clearly what you want to know. There is nothing wrong with admitting that you don't know something—in this case, something about computers or computers in education. What *is* important is that you are interested and willing to learn.

If you have a child in school, you will want to visit the school to inquire about how they use computers. You may want to talk to both a school administrator and to several teachers. What computer facilities are available for students to use? Does the school or district have a plan for helping all students to become computer literate? Does the school or district have a plan for introducing computers into the entire curriculum? Does the school or district have a plan for teacher education so that all teachers can become computer literate?

You can ask more specific questions. Perhaps the school has a computer course and a teacher who is especially interested in computers. Talk with this teacher to learn the nature of the course. Is it primarily a computer programming course or does it focus on problem solving, algorithm development and topics from computer science such as artificial intelligence, modeling and simulation and computer applications?

How did the teacher learn about computers? Has the teacher had a reasonable amount of formal instruction in this field, or is the teacher completely self-taught? Many teachers have taught themselves a great deal about computers. But this is a difficult field to master on one's own.

If you like what you see, praise the school administrators and teachers. If you don't like what you see, make some suggestions. You could loan them this booklet and suggest that they read some other **ICCE** publications. You might suggest that a committee of interested adminstrators, parents and teachers be formed. You might suggest that they seek help from teachers at other schools, from the central administrative office or a nearby college. Most teacher training institutions are now seriously interested in instructional uses of computers.

so naturally it's in the Level II manual. You're looking at the Level I."

And I was.

"I hate to ask this," I said, "but didn't we have enough to carry? Why did we bring home the Level I manual?"

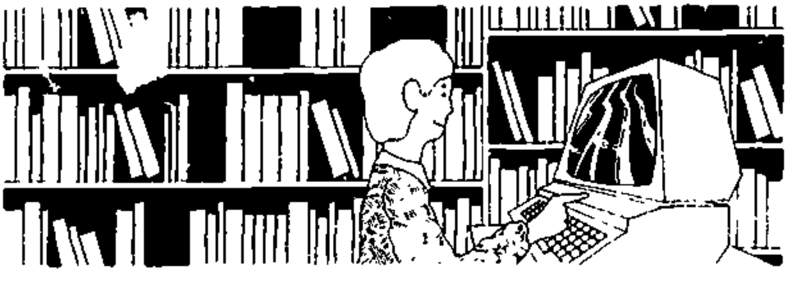
Many school districts encourage their teachers to learn more about computers by lending them equipment to use in the evening, on weekends or over vacations. Such districts often set up workshops or courses for their teachers. If you don't find evidence of such an inservice educational program for teachers, you should suggest that one be set up.

The main point is that you can encourage change. You, and a few other concerned parents, can cause a school or district to devote some energy to the issue of computers in education. This will make a difference!

A good way to enlist the aid of other parents is to work through a parent-teacher organization. Ask that part of a PTO meeting be devoted to the topic of computers in education. Perhaps the program can be put on by some local teachers and can include hands-on experience with computers. Such a program and demonstration is especially powerful if young children demonstrate what they can do and help explain it to the adults.

If the PTO shows a strong interest after the presentation, it can form a committee to meet with school administrators and teachers. Such parent interest in education is highly encouraged in most school districts. You will find your interest is especially welcome if your PTO agrees to help raise money to acquire computer equipment for use in the school.

The PTO may want to work with school personnel to set up short courses for parents and their children. These courses can make use of school facilities. Many school systems have a community education program which makes use of school facilities in the evening, and computers can be a popular part of the community education program.



In recent years, a federally-funded project called ComputerTown, USA! has explored the idea of putting computers into public libraries, schools, and other public-access locations, thereby encouraging widespread community involvement in computer education. The pilot version of the project in Menlo Park, California has experienced considerable success, and the same ideas are being implemented in a number of other cities in the United States and in England.

The ComputerTown, USA! project has produced an implementation package that will be published by Reston Publishing Company. The idea is to make computer facilities and computer instruction available through public and school libraries. Perhaps the library might purchase a quantity of computer equipment and even allow some of it to be borrowed. Perhaps educational or entertainment software might be made available in this manner.

An approach used successfully by ComputerTown, USA! is getting children involved in helping adults learn about computers. Imagine going to a computer room in the library to gain access to both a computer and a young person to help you learn about its use!

A similar approach, if applicable, is to have the science museum in your community provide computer access and instruction. A number of science museums own computer equipment and conduct classes for young people. While there is usually a charge for the classes, the cost is minimal compared to the services rendered. Often these courses are taught by young people who themselves took the course. This type of peer instruction can be excellent.

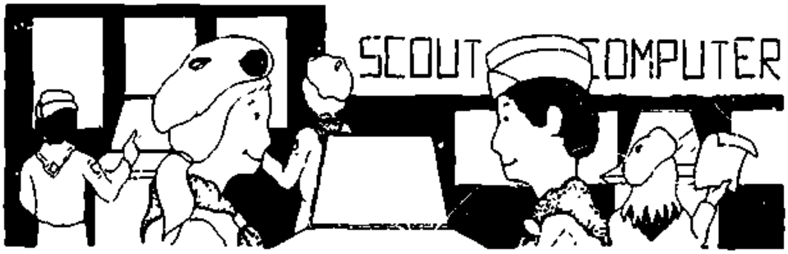
The Boy Scouts of America established a computer merit badge more than ten years ago. Organizations such as scouting often focus on special-interest topics and acti-

"Because it tells you how to work this computer."

"But I thought you just told me the Level II did that."

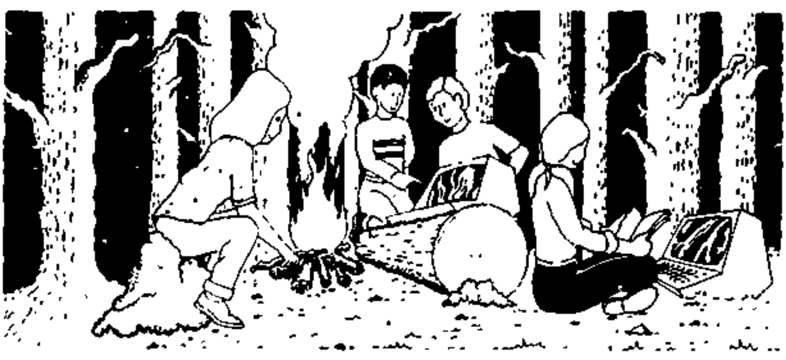
"Oh, Mom!" Computer Kid said and sighed. "They didn't write a completely new manual for the Level II. You just have to know how to use the instructions. Here look," he said, as he shoved

vities. If you have a child who belongs to one of these organizations, you may want to see if they have explored the field of computers. The organization might arrange for a film, a lecture with hands-on experience or a tour of a computer facility, perhaps with the help of a member's parent.



Closely related to this is the idea of a school computer club. The club might meet after school, taking advantage of the school's computer facilities. Students interested in forming such a club can likely find a teacher to sponsor it. Some parents may be an excellent resource. A club might have as one of its goals the raising of money to purchase more computer equipment. The club might design a course for parents, charging them to attend. Students who have done this feel that it was tremendously beneficial, both for them and for the adults. The adult students agree.

Still another approach might be to form a neighborhood computer club. All that is necessary is to find one willing parent who has a microcomputer. Some or all of the meetings might be open both to kids and adults. A computer club can be a vehicle for improving social interaction between children and adults.



There are now hundreds of computer summer camps and other opportunities for substantial instruction in use of computers. If you are thinking of sending your child to a computer summer camp, investigate it as you would any other summer camp. Look at several camps to compare costs. Find out the quantity of computer hardware and software available. What are the qualifications of the personnel? Does the program make sense to you? Does it seem mainly to be designed for entertainment, or is it designed to help students learn as much as possible? Does the camp have a good balance of educational, physical and social activities? Finally, try to talk to students who have attended the camp, and have your child talk with them.

Many computer stores offer computer courses. These courses vary widely in quality and cost. Some are excellent, quite suited to the needs of young students. Others are primarily for business people who are thinking of buying a computer. It is reasonable to enroll both yourself and your child in such a course. It is fun to see what kinds of things your child learns faster and more easily than you, and where you seem to have the advantage. Children are put in situations where they are learning new things every day. Many adults avoid such learning situations. Taking a class with your child may feel threatening to you at first but likely will become a rewarding and enjoyable experience.

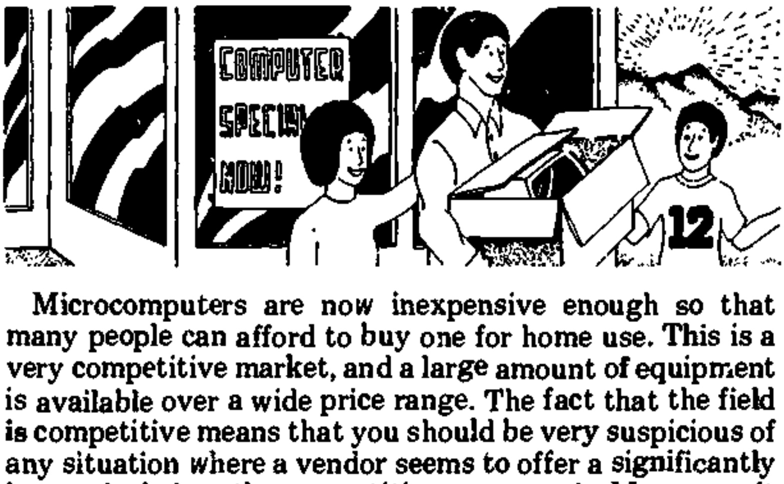
The main point is for you and your children to gain more knowledge about computers. Computer access, with substantial hands-on experience and some instruction, is highly desirable. Such access may be achieved through schools, stores, computer camps, science museums and libraries. Still another alternative is to purchase a computer for your home. Some guidelines are given in the next section.

both manuals at me before being drawn back outside by the enticing sound of the Pruner's saw.

Of course it was only natural for Computer Kid to use the Level I manual for the Level II computer when the Level II manual was needed to discover how to turn the machine on and heaven knows

PART VII — BUYER'S PLAN

Over the next few years, many millions of people will buy microcomputer systems for home use. Some will spend as little as $100, while others will spend more than $3,000. The wide price range and variety of equipment make it difficult to decide what to buy. This section discusses the major decisions you will need to make and provide guidance in making these decisions.



Microcomputers are now inexpensive enough so that many people can afford to buy one for home use. This is a very competitive market, and a large amount of equipment is available over a wide price range. The fact that the field is competitive means that you should be very suspicious of any situation where a vendor seems to offer a significantly better deal than the competition can match. Moreover, it means that there is no one "best" computer. If the major brands were not competitive with each other, the non-competitive ones would soon be out of business.

what else. The whole thing was a conspiracy against people like me, and I recognized it at once. The wire hookups, the hidden on/off switch and the "treasure hunt" style manuals were designed to intimidate those who reasoned that if computers were so advanced, the machines could certainly come in one completely

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The buying plan should proceed in two phases. The first phase is informal. It includes reading material such as this booklet, getting some hands-on experience, talking to people who own computers and thinking about why you want a home computer. The second phase is more formal. It involves making lists of how you would use a home computer, what hardware, software and support services are needed and what they cost. Ideas for consideration during the first phase are discussed first, followed by some suggestions on how to carry out a more formal process leading to a purchasing decision.

First Phase (Informal Considerations)

Why do you want a home computer? Is it for education, entertainment or business? Perhaps it is for all three. If so, what percentage of usage will fall into each category? Who will use the computer, and how much will it be used by each person? How much usage will be necessary before you feel you have gotten your money's worth?

The nature of the intended usage provides a basis for the type of equipment needed. A computer to be used strictly for home video games can have quite limited capabilities and need not have a printer. Such a system is nearly useless for any serious business purposes and has only limited educational value.

Is the system to be used as a word processor? If so, you will need at least one disk drive, a reasonable quality printer and word processing software. This generally means that you are in the \$2,000-\$2,500 price range. Will you and your family get your money's worth out of such an investment?

You may feel that a home computer will help your children's education. How? Will you acquire educational software such as drill and practice materials, programmed instruction materials and educational simulations? Such software may cost more than the original computer system. How will you select these materials? Much of this type of software is available only through mail order houses, may be of relatively poor quality, and may not necessarily fit in well with the type of instruction your child is receiving in school.

Alternatively, you may attempt to acquire public domain software or develop your own software. There is a considerable quantity of software available for the taking. However, its quality is often poor when compared to commercially available, copyrighted software. You should also be aware that it is both unethical and illegal to reproduce such copyrighted software.

The point is, it is a major task to acquire a large collection of software suited to a child's changing educational needs. You might want to check with your child's school about this. If the school is already using computers for CAL, you might want to purchase the same type of computer and arrange to borrow software from the school. Eventually, schools and public libraries will lend software just as they now lend books.

Another possible approach is that you might purchase a computer so that your child can learn to write programs. If so, consider who will do the instruction and answer questions. Are you willing to work with your child and learn to program? Some children can learn programming strictly on their own, but this is not typical. At least, investigate instructional options before purchasing a computer for you or your child to learn to program.

Perhaps the very best reason for acquiring a home computer system is for you and your family to learn more about computers and for all of you to learn to take advantage of what computers have to offer. You should try to involve the whole family in the acquisition of educational and entertainment software that suits all of your needs.

The purchase of a new T.V. set is relatively simple compared to the purchase of a home computer. Not only do computers vary over a wider price range, but the initial cost may be only a small fraction of the total cost. We have discussed the need for software, which can easily cost more

assembled part containing an obvious on/off switch and have a manual which could be followed page by page. The Computer Age was a devious plot structured to make an average person think that this technology was only open to the mathematically-minded. On/off switch equals computer divided by two and so on.

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than the hardware. But what about additional hardware such as disk drives, a printer or graphics tablet? Some computer systems easily allow for such expansion, while others lock you into a minimal, non-expandable system.

Once you acquire a particular computer system, you will probably keep it for a number of years. You will put a lot of time into learning to use that particular system, and you may put a good deal of money into software for the system. Acquisition of a new system might give you a more capable and less expensive computer, but it might also negate quite a bit of the original investment you have made in learning and in software.

There are exceptions to this, of course. Some people take the approach that they will purchase an inexpensive system to "test the water." Their intent is to acquire a more expensive system if their initial experience is rewarding and a better computer system seems worthwhile.

You know that many T.V. repair shops can fix your T.V. What do you do if your computer breaks? Some computer sales outlets are set up to provide excellent and rapid repair service. Others provide poor quality and/or no service. If you need a computer for business and educational purposes, you will not want to do without the machine for several weeks while it is being shipped out of town for repair. This is an important consideration when selecting a vendor.

Finally, you will almost certainly need technical assistance. A piece of software doesn't function as you think it should. You are having trouble reading the computer manual that came with the machine. You need advice on what equipment can be added to your computer system. Where do you turn? Once again, your vendor is a logical choice, provided you have selected wisely.

Second Phase (Formal Considerations)

The formal phase should proceed in four steps:

1. **Needs Assessment**

   Who will use the computer, for what purposes, and to what extent?

2. **Implementation Assessment**
   What hardware, software and support services will meet the uses you have identified in Step 1?

3. **Comparison Shopping**
   Find two or more vendors who can provide the needed systems and services.

4. **Final Decision**
   Reconsider Steps 1-3 above, and repeat as necessary. Make a final decision and carry it out. If a better system comes out later, remember that you made the best decision at the time.

STEP 1—NEEDS ASSESSMENT

The first step is to decide how the computer system is to be used. Talk it over with members of your family and with other people who may use the system. Then, make a table such as the one in Figure 1 below:

(Figure 1.)

NEEDS ASSESSMENT

List names of people along the top.

List applications below:	User #1	User #2	User #3	User #4
Education				
1 Spelling drill				
2 Word processing				
3 Math concepts				
4 Programming				

I had, however, found the secret. In one afternoon I learned about power jacks, computer backs, and ENTER keys. With this knowledge I had, like Neil Armstrong, taken a giant step forward—this one for one aging history major suffering from mathematical regression. I hadn't exactly tiptoed gracefully into

Business				
1 Bid specifications				
2 Budgeting				
3				
4				
Entertainment				
1 Adventure games				
2 Computer chess				
3 Computer graphics				
4 Music composition				
Other				
1 Address lists				
2 Income tax				
3 Record inventory				
4 House insurance inventory				
5				
6				
7				

Use this space to estimate the number of minutes of use per week in each category.

List all people who will use the computer along the top. Along the left side, list the applications they propose, divided into categories such as Education, Business, Entertainment and Other. If these categories don't fit your needs, make up your own. Under each major application heading, list more detailed applications. Be as specific as you can. Some applications may require special hardware, software or other support. For example, one educational application to consider is learning to program in Logo. This computer language promises to become an important way to learn mathematical concepts and problem-solving techniques. It's also a lot of fun. Logo is not available on many

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computers, and is an add-on expense on every computer system.

Now, fill in the table with estimates of the expected number of minutes of use per week. This will give you a good idea of how much the computer system will be used, and it may help you decide how much money to spend. It may well be that once you have a computer, you will find more and more uses for it. But unless you have some definite applications in mind to begin with, chances are your computer will see little use.

STEP 2—IMPLEMENTATION ASSESSMENT

You are now ready for Step 2. Analyze the *Needs Assessment* chart you have just completed. What hardware, software and support services are required to meet your needs? You may want to visit some computer stores or talk with a computer expert to find out what hardware/software is needed for your specific needs such as word processing, income tax preparation, producing mailing labels or learning to program in a particular language.

Support services are also an important consideration. Such services include courses in how to use the computer, question-answering, equipment repair or help in finding information. The support services you need will vary with the degree of computer knowledge you have and how your computer will be used. In any event, you will certainly want to know the nature of the warranty on the equipment, where it can be repaired, and how long typical repairs take as well as the cost.

You can summarize your minimal hardware, software and support service needs on the left-hand column of the *Implementation Assessment* table. Leave columns at the right to be filled in with specific prices and make/model numbers as you visit computer vendors. A partially filled-

the Computer Age; instead I stumbled into the vestibule at least, and I was, with my avant-garde and very professional feeling now in full bloom, "ready" to cross the door jamb.

"Hey Mom," Computer Kid yelled from the kitchen where I reasoned he was munching on the cookies I was supposed to take

out example is given in Figure 2 below.

(Figure 2.)

IMPLEMENTATION ASSESSMENT

	Vendor #1	Vendor #2	Vendor #3
Hardware			
1 Color monitor			
2 ..oppy disk			
3 Medium quality printer			
4 Typewriter quality Keyboard			
Software			
1 Word processor			
2 Address label system			
3 Logo language			
4 Games			
Support Services			
1 Repairs done in less than one week			
2 Intro. course for self and one child			
3			
4			

Use this space to fill in make/model number and prices.

STEP 3—COMPARISON SHOPPING

Now, armed with your *Needs Assessment* and *Implementation Assessment* papers, visit several stores that sell computer systems and begin to fill in the boxes on your *Implementation Assessment* sheet. It makes good sense to visit at least three different vendors if you can—a home computer is a serious purchase that will have a definite effect on your family.

(It is likely that you will want to revise your *Needs Assessment* and *Implementation Assessment* after visiting one or two vendors. This is because you will be learning more all the time, and you will be getting better insight into what is available to meet your needs. If you make revisions, you may want to revisit some vendors.)

STEP 4—FINAL DECISION

Finally, your *Implementation Assessment* sheet is filled with comparison shopping data. It is time to make a decision. Mail order outlets usually offer lower prices, but price alone is unlikely to be the sole basis for your decision. How do you compare a friendly, knowledgeable, local salesperson with a mail order outlet? How do you compare "Repairs will be completed within one working day or we will provide a loaner" with "Send us your machine via UPS and we will mail you an estimate of what repairs will cost"? You will need to decide how to weigh hardware costs and capabilities, software costs and availability, and various support services. This will not be too difficult if you have carefully followed the first three steps discussed in this section.

You are now at the end of the main part of this booklet. What remains are appendices containing a glossary and sources of additional information.

You already have considerable information—indeed, you may feel overwhelmed! The field of computer and information science is very large, very complex and growing rapidly. Computers may well be the biggest thing to happen to education during your lifetime.

But that is all the more reason why you should try to make sure that your children learn about computers. By the year 2000, computers will be commonplace in most

to the church coffee hour, "Have you made it to page two yet?"
"In which manual?" I asked, thinking how much easier the Battle of Baltimore had been.

places of employment and throughout all levels of education. People who cannot use computers freely and easily will be at a severe disadvantage in many occupations.

You may well be one of the people who need to learn more about computers. If so, it is quite likely that you will eventually want to acquire a computer for home use. Begin now by building your knowledge base, following the ideas given in this booklet. It promises to be an adventure that you and your children can explore together.

PART VIII APPENDICES

GLOSSARY

Algorithm
A finite, step-by-step set of directions guaranteed to solve a specified type of problem. Algorithms are an important part of mathematics. Students learn algorithms for the addition, subtraction, multiplication and division of whole numbers, decimal fractions and fractions. The term algorithm can also be used to describe a procedure for looking up a word in a dictionary or for alphabetizing a list of words. See also: *Procedure.*

Artificial Intelligence (AI)
The branch of computer science that studies how smart a machine is or can be. Computers can play chess, checkers or backgammon at the level of a state champion. They can assist in medical diagnosis, aid in foreign language translation, and even carry on a limited conversation. Research in AI has led to computers that can accept spoken commands and can "see" using a television camera for an eye. The range of problems that AI can help solve is continually increasing and overlaps greatly with the types of problems students study in school. This raises the issue of what people should learn to do mentally, what they should learn to do using pencil and paper or other simple aids, and what they should learn to do making use of a computer. This is one of the most challenging curriculum problems our schools have ever faced.

BASIC
A computer programming language developed by Kemeny and Kurtz at Dartmouth College in the early 1960s and now available for use on almost all computers.

The language was specifically designed to fit the needs of college students, but the language is also widely used in business, in precollege education and by people who have home computers. (See *Logo* and *Pascal* for a brief discussion of other programming languages suited to the needs of precollege students.)

Binary digit

One of the symbols 0 or 1; often called a *bit*. The binary number system uses just two symbols to represent numbers. Starting at zero, binary counting goes 0, 1, 10, 11, 100, 101, 110, 111, 1000, 1001, and so on. These correspond to the decimal notation numbers 0, 1, 2, 3, 4, and so on.

Electronic circuitry can easily be designed to represent binary symbols (for example, current is flowing or not flowing) so that computer designers have chosen to use the binary number system inside of computers. Algorithms exist for translating between binary and base 10 notation, and these are incorporated into most computer systems. Thus, computer users enter their data using base 10 notation and receive their answers in base 10 notation, while the computer actually carries out computations using binary circuitry.

Bit

Binary digit.

Bug

An error in a computer program. The process of searching for bugs and correcting them is an important part of computer science and is called *debugging*.

Byte

One character of computer memory storage. In describing a computer, one frequenlty gives the number of bytes of internal storage and then discusses the external storage. For example, a microcomputer may have a 48K (K=1024) internal memory and have two floppy disk drives, each using disks with a capacity of about 150,000 bytes.

Cathode Ray Tube (CRT)

The picture tube of a television set, and the type of display screen used on most computers. Depending on the computer system, a CRT may be limited to displaying just alphabetic and numeric characters in black and white, or it may be able to display full color graphics.

Central Processing Unit (CPU)

The part of computer hardware that fetches instructions from internal memory, interprets their meaning and carries out the instructions. The CPU of a modern, medium scale computer may be able to process ten million instructions per second.

Character

A letter, digit, punctuation mark or other symbol from a specified symbol set. A computer is designed to work with characters and with strings of characters. For example, a word is a string of one or more alphabetic characters and a number is a string of one or more numeric characters.

Chip

A fingernail-sized circuit containing a large number of transistors and connecting components, often called an *integrated circuit.* It is called a chip because the manufacturing process makes use of a piece (chip) of silicon. The transistor was invented in 1947 and became commonplace in computers in the early 1960s. Soon people learned to manufacture a single circuit containing the equivalent of dozens or hundreds of transistors and other electronic components. The number of components in an integrated circuit has grown over the years, so that now people speak of large scale integrated circuits (LSI) and very large scale integrated circuits (VLSI). Currently it is possible to manufacture a single chip containing the equivalent of about a half million transistors and other electronic components. Such a VLSI may serve as the CPU of a powerful microcomputer.

Computer graphics

The use of a computer to deal with pictures, drawings, graphs. Computers are quite useful in commercial art and are now standardly used to help draw the cartoon shows one sees on television. Recent science fiction movies have made extensive use of computer-generated sequences. Computer graphics is of growing importance in business and industry since it provides a powerful tool for the manipulation and display of complicated data.

COBOL

COmmon Business Oriented Language, a programming language especially designed for use in business. Now more than twenty years old, this language is still the most widely used programming language for business problems. Since the language was designed strictly for use in business data processing departments, it is not a good first programming language for most students.

Computer-Assisted Learning (CAL)

Any use of computers to aid in the teaching and/or learning process. Early research in CAL began in the 1950s, and now many thousands of studies have been completed. These studies have helped lead to improvements in the quality and overall usefulness of CAL. It seems likely that CAL will grow in importance and will eventually be the dominant mode of instruction in our schools.

Computer Literacy

This widely used term is not precisely defined, but refers to a level of computer knowledge and skills. Many educators suggest that all students or teachers should become computer literate. This generally means that students and teachers should gain a functional, working level of knowledge, suited to their everyday needs.

Disk

A flat, circular plate coated with magnetic iron oxide and used as an external storage device in computers. A single floppy disk may store 150,000 characters while a hard disk pack may store a half billion characters or more. A disk drive gives rapid access to programs and data stored on a disk.

Hardware

The physical machinery part of a computer system. It includes input, storage, manipulation and output units. The hardware for a complete computer system may range in price from a few hundred dollars to many millions of dollars.

Information Retrieval (IR)

The computerized storage and retrieval of information. The external storage devices used on computers are large enough to store a dictionary, encyclopedia or large numbers of books. Eventually these devices will store huge libraries. IR is now commonplace in business, government and research. Eventually it will be common in schools and homes.

Internal Memory

The fast-memory part of a computer's storage system. It contains the program that is being run and the data as it is being processed. An inexpensive microcomputer may have an internal memory that stores a few thousand characters while the most expensive computers have internal memories that store millions of characters.

K

Computer scientists use this symbol as a measure of storage capacity, with K = 1024. This is the number 2 raised to the 10th power.

Logo

A programming language developed by Seymour Papert especially for use by young children. The language makes it particularly easy for solving certain computer graphics problems, learning some aspects of geometry and for learning some important ideas about programming.

Microcomputer

Any computer whose CPU consists of one or a small number of large scale or very large scale integrated circuits. Generally a microcomputer system is priced under $10,000, although there are no precise bounds on this.

Microsecond
A millionth of a second. A medium-speed computer, costing perhaps a half million dollars, can perform ten multiplications in a microsecond. Such a computer can do more arithmetic in a minute than a person is apt to do by hand in a lifetime.

Modeling and Simulation
A model is a representation of certain key features of an object or system being studied. Scientific models often make use of complex mathematical formulas: use of the models may require substantial amounts of computation. Computers are now a common aid to modeling. This part of computer and information science is called modeling and simulation.

Nanosecond
A billionth of a second. The very fastest computers now under construction are approaching a speed of one operation per nanosecond. Soon we will have a computer that can count from 1 to 1,000,000,000 by 1's in a single second!

Optical Character Recognition
The machine reading of mark sense scan sheets, bar codes and typewritten and printed materials. This is now a common method of inputting data to a computer system.

Pascal
A programming language especially developed for use in computer and information science courses. It is now commonly used in the first college course for students planning to major in computer and information science. Pascal is a substantially more complex programming language than BASIC or Logo.

Procedure
A detailed, step-by-step plan for solving a specified type of problem. There is no guarantee that the plan will work (it may contain a bug). Computer scientists are interested in procedures that can be carried out by a computer; such procedures are called computer programs. (See also *Algorithm.*)

Software

A detailed, step-by-step set of directions designed to be carried out by the hardware of a computer system. A computer system consists of hardware and software. In many applications the software may cost as much or more than the hardware. However, if a piece of software is widely used, its development cost can be shared among many users, so the retail price may be quite modest. Some very sophisticated computer games and/or instructional programs sell in the $20-$50 price range.

Timeshared Computing

A form of interactive computing in which a number of terminals share the memory and central processing facilities of a computer system. This decreases the cost per user and can allow convenient communication among the users.

Word Processing

Use of a computer system as an automated typewriter. Material being typed can be viewed on a display screen, so that corrections are made before one outputs to paper. Stored material such as standard addresses, paragraphs or form letters can be used to increase the productivity of a word processor operator.

RESOURCES

Books

ComputerTown, USA!'s Implementation Package is being published by Reston, Publishing Co. For further information contact CTUSA!, P.O. Box E, Menlo Park, CA 94025.

Harper, Dennis O. and Stewart, James H., Editors: *Run: Computer Education*. Brook/Cole Publishing Co. 1983. $15.95.

This book is an extensive collection of articles and papers which deal with many of the facets of computers in the educational process.

Moursund, David: *Introduction to Computers in Education for Elementary and Middle School Teachers*. International Council for Computers in Education, 135 Education, University of Oregon, Eugene, OR 97403, 1981. $7.00.

This book is designed for self-instruction or for a formal inservice or preservice course for teachers.

Papert, Seymour: *Mindstorms: Children, Computers and Powerful Ideas*. Basic Books, 1980.

This is a revolutionary view of the learning that can go on when children, computers and the Logo language are combined.

Taylor, Robert, Editor: *The Computer in the School: Tutor, Tool, Tutee*. Teachers College Press, 1980.

This collection features papers from five leading thinkers in educational computing: Alfred Bork, Thomas Dwyer, Arthur Luehrmann, Seymour Papert and Patrick Suppes.

Magazines

Classroom Computer News: Intentional Educations, Inc., 341 Mt. Auburn Street, Watertown, MA 02172. (One year/6 issues—$16.)

CCN addresses the use of microcomputer technology within the traditional classroom environment.

The Computing Teacher: Education 135, University of Oregon, Eugene, OR 97403. (One year/9 issues—$16.50.)

This is the journal of The International Council for Computers in Education. The articles are written by educators in the field.

Creative Computing: P.O. Box 789-M, Morristown, NJ 07960. (One year—12 issues—$24.97.)

This magazine offers general coverage of home computing, with frequent articles on educational computing.

Electronic Learning: Scholastic Inc., 902 Sylvan Avenue, Box 2001, Englewood Cliffs, NJ 07632. (One year/8 issues —$15.)

This publication offers non-technical articles and columns dealing with the applications of microcomputers to education.

Infoworld: 375 Cochituate Road, Box 880, Framingham, MA 01701. (One year/52 issues—$25.00.)

Infoworld is a newsweekly for microcomputer uses, addressing ali facets of the field.

There are numerous other general and specialized journals and magazines which deal with microcomputing. Browse the magazine rack in your local computer store to find your favorite.

ICCE also publishes:

The Computing Teacher Magazine

An Introduction to Computing: Content for a High School Course

Teacher's Guide to Computers in the Elementary School

School Administrator's Introduction to Instructional Use of Computers

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